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FINAL REPORT

Part II

Contract No. W23-072-ORD-2123
War Department
Ordnance Department
Small Arms Branch

710/858-11

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MIDWEST RESEARCH INSTITUTE

ENGINEERING MECHANICS DIVISION

Project No. 2-S48-E

FINAL REPORT

Part II of Two Parts

Part I - A Method for Predicting the Performance of Light Armor

Part II - A Six-Channel, High Frequency, Transient Recorder Designed For Study of the Mechanism of Light Armor Performance

Prepared For
War Department
Ordnance Department
Small Arms Branch
Under Contract No. W23-072-ORD-2123

THE DEVELOPMENT OF EQUIPMENT AND METHODS FOR STUDYING THE DYNAMICS OF THE PERFORMANCE OF LIGHT ARMOR CONSISTING OF FIBROUS OR A COMBINATION OF FIBROUS AND METALLIC MATERIALS

Project Report No. 21

November 15, 1948 Copy No. 6

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PART II

SUMMARY

This section describes the salient features of a six channel high frequency transient recorder which employs three double gun cathode ray tubes. All units of the equipment are assembled into a single rack-type cabinet. The purpose of the equipment is to provide for independent but simultaneous recording of as many as six transient phenomena having high frequency characteristics which the usual galvanometer type of instrument cannot follow. A typical application is the problem of taking strain gage measurements of stresses set up in armor plate around the point of impact of a projectile. The instrument provides for simultaneous recording of the individual strain gage responses on 35 MM film. The vertical deflection amplifier provides a frequency response of from below 10 to 200,000 cycles per sec. and sensitivity of 0.4 millivolts per inch of deflection. The sweep generator provides a linear time axis at a rate of between .2 and 5 milliseconds. Provision is made for single trace or repetitive triggering of the sweep generator. The entire unit weighs about 235 pounds. Overall dimensions are width, 32 1/2 inches, depth 24 inches and height 24 1/2 inches.

I. INTRODUCTION

The design of the six channel high frequency recorder was undertaken in order to facilitate the taking of a number of simultaneous stress measurements in connection with the armor evaluation program. As far as is known there is no instrument commercially available, which will meet the requirements. Photographs of the overall assembly are shown in Figure 12. The recorder may be broken down into the following functional units:

1. Six vertical deflection amplifiers,
2. Three type 5SP11 CR tubes,
3. One sweep generator,
4. One low voltage power supply,
5. One high voltage power supply,
6. One calibration unit,
7. One cabinet rack assembly,
8. Three camera and hood assemblies, Dumont Type 271-A.

Full consideration has been given toward designing the instrument for maximum versatility and yet keep the size and weight at reasonable figures.

II. VERTICAL DEFLECTION AMPLIFIER

A. Electrical Description

The schematic diagram is shown in Figures 1 and 2. A novel feature is the use of two separate chassis units per amplifier namely, preamplifier and main amplifier. The preamplifier is designed to plug into the main amplifier so that it may be removed to a remote point in the event it is not feasible to locate the entire recording unit close to the strain gages or other source of signal. Short connections may then be made between the gages and preamplifiers and the relatively high level output voltage can be fed to the main amplifier via a remote cable of considerable length. Miniature type tubes are used throughout.

The preamplifier provides a high impedance input of 500,000 ohms. The first stage employs a high gain pentode while the second and third stages are served by a twin triode. The third stage is a cathode follower which provides a low impedance output for the remote line. Negative feedback is applied between the cathodes of the first and third stages. The voltage gain is 35 db and input signal limits are 50 microvolts minimum and 0.1 volt maximum. Peaking coils are used in the plate circuits of the first two stages extending the high frequency cut-off to 200 kc. The main amplifier has an input impedance of 10,000 ohms which is established by the volume control located between the input terminals and the first grid. A twin triode, provides two stages of amplification. Push-pull output is provided by a pair of 6AQ5's, one of which serves as a grounded grid type of phase inverter. Negative feedback is applied between the output plate circuit and the cathode circuit of the second amplifier stage. The gain is about 60 db. The available peak to peak output voltage is 450 V. Shunt-beaking coils are used in the plate circuits of all stages. A plot of the frequency response characteristic is shown in Figure 14.

B. Mechanical Description

Pictures of the preamplifier and main amplifier are shown in Figure 3. In order that the preamplifier may be readily removed for use at a remote point, a Jones type of connector is used for attaching the units, and a six conductor cable provides for inter-unit connection during remote operation. Both units are equipped with light duty rubber shock mounts in order to minimize microphonic effects due to vibration. Care has been taken to design the units so as to occupy as little space as possible since six amplifier assemblies are required, that is, a vertical deflection amplifier for each of the six channels. It was also necessary to reduce weight as much as possible. The chassis are fabricated from aluminum, and miniature components have been used where ever possible. Overall dimensions of the preamplifier are 4 inches by 2 inches by 4 inches high and main amplifier 6 inches by 4 inches by 4 1/2 inches high.

C. Specifications

1.	Overall voltage gain	100 db
2.	Frequency response	below 10 cycles to 200 kc.
3.	Sensitivity	400 microvolts (RMS)/inch of def.
4.	Max. output voltage	450 v. peak to peak
5.	Distortion	5 percent max.
6.	Power requirement	450 V.D.C. at 20 M.A.
		300 V.D.C. at 10 M.A.
		6.3 V.A.C. 2 Amps.
7.	Overall dimensions	8 inches L. by 4 inches W. by 4 1/2 inches H.

III. SWEEP GENERATOR

A. Electrical Description

Schematic diagrams of the sweep generator are shown in Figure 4 and 5. The trigger and delay circuits shown in Figure 4 employ conventional multivibrators or commonly called "flip-flop" circuits. The sweep can be triggered either remotely or at the front panel. Remote triggering can be accomplished by impressing either a negative or positive voltage of value determined by the setting of R1 or by opening or closing the trigger line. A negative voltage or short circuit will trigger V1 with connections as shown while applying a positive voltage to the grid of V2 or opening a short across its grid resistor will cause it to fire.

The degree of time delay is determined by the position of variable resistor, R2 , in the grid circuit of V3 . The delay may be varied over a range of 0.5 to 5 milliseconds. Switch S3 is mounted on the back of R2 and switches the delay circuit "on" and "off" at the extreme counterclockwise position.

A third multivibrator circuit serves as a sweep timing circuit. The voltage from the trigger or delay circuits are impressed on the grid of V7 causing this tube to start oscillating in conjunction with V8 . The grids of the C-R tubes are intensified by the change in voltage on R4 . Also, V5 and V6 are triggered and capacitor C becomes charged. The rate of sweep is adjustable from 0.5 to 5 milliseconds by variable resistor, R5 , in the grid circuit of V7 .

The capacitor voltage is applied to the grid of V9 which is the first stage of a push-pull amplifier commonly called a "long tailed pair". The grid of V10 follows the unbalance voltage in the common cathode resistor. A horizontal deflection voltage of 450V is obtained which is sufficient to provide a full five inch deflection on the C-R tube face.

B. <u>Mechanical Description</u>

A view of the sweep generator is shown in Figure 6. All controls which require frequent adjustment are located on the front panel and connected by cabling to the sweep generator chassis. In order to conserve space miniature tubes are used. Internal terminations such as power supply, blanking, trigger and sweep voltages are made at a terminal strip located at the front of the chassis while remote terminations are provided by a Jones type connector at the back of the chassis. The crystal oscillator unit which generates the calibration pips is also mounted on the sweep generator chassis. Overall dimensions of this unit are 7 inches by 9 inches by 4 1/2 inches H.

C. Specifications

1.	Delay Time	0.5 to 5 Milliseconds
2.	Sweep Time	0.5 to 5 Milliseconds
3.	Sweep Voltage	450V. Peak
4.	Over-all Dimensions	7 inches x 9 inches x 4 1/2 inches H.

IV. LOW VOLTAGE POWER SUPPLY

A. Electrical Description

The low voltage power supply is of conventional design as shown in schematic diagram, Figure 7. It supplies voltage values of plus 450, plus 300 and minus 150. The 300 volt supply is electronically regulated by means of the direct current amplifier stage employing a type 6AU6 and four type 6L6 regulator tubes. A screw driver adjustable control permits setting the voltage at any value between 250 and 350 volts. The 450 V. supply is unregulated while the minus 150V. supply employs a type OA2 gas tube regulator. The ripple in all three voltage sources is extremely low.

B. Mechanical Description

A photograph of the low voltage power supply is shown in Figure 6. Outline dimensions of the unit are 11 1/4 inches W. by 20 inches L. by 8 inches H. Since the chassis must support considerable weight it is made of heavy gauge aluminum and reinforced at the center with a strip of metal attached at each end to the chassis sides. A terminal strip located at the rear and top of the chassis provides for all terminations. All tubes are located at the rear of the chassis so that they will be accessible for replacement.

C. Specifications

1.	Supply Voltage	110V., 1 ϕ, 60 cycles
2.	No. 1 D.C. Output	Plus 450V., 175 M.A.
	No. 2 " "	Plus 300 V., 175 M.A.
	No. 3 " "	Minus 150 V., 50 M.A.
3.	Overall Dimensions	11 1/4 inches by 20 inches by 8 inches H.

V. HIGH VOLTAGE POWER SUPPLY C-R TUBE CONTROLS

A. Electrical Description

The schematic for the high voltage power supply and cathode ray tube positioning controls is shown in Figure 8. The plate transformer supplies 1500 volts RMS to a voltage doubler circuit employing two type 2X2 rectifiers. Thus, the intensifier electrode of the C-R tube operates at 3500 volts and the accelerating electrode at 1500 volts with respect to the cathode. Resistance-capacitance type of filtering is used in each section of the supply with the addition of a series tuned resonant circuit in the section which supplies the control electrode in order to eliminate intensity modulation by ripple voltage. In order to minimize interaction of focus and intensity controls between channels, it was found necessary to draw a heavier bleeder current from this section of the supply so that the current drawn by these control circuits would be only 10 percent of the total current drain. The intensity and focus control potentiometers of the respective six channels are paralleled as shown in Figure 8. Dual potentiometers R1 and R2 serve as positioning alignment controls for the horizontal and vertical deflection plates respectively, and dual potentiometers R3 and R4 provide for positioning the horizontal and vertical traces with respect to this alignment point. The type 6AL5 diodes in the horizontal positioning circuit serve to discharge the coupling capacitors and enable use of a rapidly repetitive sweep.

B. Mechanical Description

The high voltage power supply chassis as shown in Figure 6 is similar in construction to that of the low voltage power supply. Low voltage terminations are made at a terminal strip located at the rear and top of the chassis. The two high voltage terminals are an insulated type (MILLEN #37001). All high voltage wiring points are located at the under side of the chassis so that personnel can not easily co in contact with them. Overall dimensions are 9 inches W. by 20 inches L by 7 inches H.

C. Specifications

1.	Supply voltage	110V., 1Ø, 60 cycles
2.	No. 1 D.C. Output	Plus 2000V., 5 M.A.
	No. 2 " "	Minus 1500 V., 10 M.A.
3.	No. 1 A.C. Output	6.3V., 20A.
	No. 2 " "	2½V., 2A.

4. Overall Dimensions 9 inches W. by 20 inches L. by 8 inches H.

VI. CALIBRATION UNIT

A. Electrical Description

The calibration unit provides a reference signal to accurately establish the sensitivity and time characteristic of the overall recording system. The time reference is provided by a Hammarlund Type FS-135-C frequency standard which is crystal controlled. This serves to trigger a multivibrator circuit which generates marker pips at intervals of 50, 100, 250 and 500 microseconds as selected by the respective positions of a four position switch (see Figure 9). The sensitivity reference is provided by a 1 1/2V. battery and voltage divider by means of which the calibration voltage may be set to any desired value as read on an accurate millivoltmeter (see Figure 10). The timing pips are superimposed on the D.C. sensitivity reference and applied to the input of the vertical deflection amplifiers. Relays are provided for remote switching of the amplifier inputs from the strain gauges to the calibration source. Then it is simply necessary to push the calibrate push button switch on the front panel of the main unit in order to trigger the sweep generator and actuate the calibrating relay. The latter relay is a sensitive plate current operated type and has mercury type contacts to eliminate contact bounce and arcing. It is a Western Electric type D-168479 mercury relay with case No. 22108.

B. Mechanical Description

The crystal oscillator, multivibrator and trigger circuit components are mounted on the same chassis as the sweep generator. However the 1 1/2 V., battery, calibration relay, channel switching relays and channel terminating boards are mounted in a sheet metal box that can be readily removed at the back of the main unit through the rear access door and located in the proximity of the strain gauges. A photo of this box is shown in Figure 6. Two 8 terminal boards are located on one side of the box and a four terminal Jones type connector on the opposite side. One terminal strip is used for the six strain gauge wires and the other for the input wiring to the vertical amplifiers. The Jones connector is used for the termination of the remote cable which connects the calibration box to the sweep generator. A jumper cable is used to complete this remote connection at the main unit when the calibration box is remotely located.

C. Specifications

1.	Cal. pip intervals	50 microsec
		100 "
		250 "
		500 "
2.	Cal. voltage range	0 to 30 millivolts
3.	Over-all dimensions	8 1/2 inches W. x 5 3/4 inches D. x 5 1/2 inches H.

VII. OVERALL ASSEMBLY

Electrical Description

A block diagram of the overall equipment is shown in Figure 11. Connections to the calibration unit are shown with a broken line since it may be removed from the main unit and located near the strain gauges. In this case the preamplifiers of the vertical deflection amplifiers are also remotely located so that connections between the calibration unit and preamplifiers may be as short as possible.

Terminations for all external connections to the main unit are located at the back as shown in Figure 12 (c). Jumper cables are provided for completing amplifier and calibration circuits when the preamplifiers and calibration unit are remotely located.

All horizontal and vertical deflection plates are directly connected to phone jacks at the top of the cabinet as shown in Figure 12 (a). Switch contacts are provided in these jacks so that when the phone plugs are inserted the deflection plates are isolated from all internal circuits and external positioning and deflection voltages may be directly applied.

All controls are located on the front panel (see Figure 12 (a). Those immediately above and below the cathode ray tubes control the top and bottom "guns" respectively. From left to right the controls function as follows:

1. Vertical Position
2. Intensity
3. Vertical Amp. Gain
4. Focus
5. Horizontal Position

Controls on the lower front panel as viewed from left to right and top to bottom serve as follows:

1. Sweep trigger (test) switch
2. Sweep reset switch
3. Calibrate switch

4. Sweep selector switch "Single - Repeat"

5. Sweep amplitude control

6. Sweep duration control

7. Sweep delay time control

8. Calibration switch, "Off-On"

9. Calibration Frequency control

10. Calibration "pip" amplitude control

11. Low voltage power supply switch, "On-Off"

12. Low voltage plate supply switch, "On-Off"

13. High voltage power supply switch, "On-Off"

Three fuses are mounted at the back of the cabinet adjacent to the power connector. They are located relative to the connector as follows:

1. Low voltage power supply fuse, Type 3AG,5A.
2. " " plate " " " " "
3. High voltage power supply fuse, Type 8AG, 3/4A.

B. Mechanical Description

The frame or rack of the cabinet is fabricated of angle iron. All the panels and shelves are fabricated of aluminum in order to reduce weight. Rubber mounting feet are provided at each of the four corners in order to reduce the microphonic effects of vibration. The two power supplies, sweep generator and calibration unit are mounted on the bottom shelf while the six vertical deflection amplifiers are mounted on the upper shelf immediately below the cathode ray tubes. Each amplifier is supported by flexible rubber posts in order to further reduce microphonic effects. A bakelite panel serves as a mounting means for all the positioning, focus and intensity control components. This panel extends across the cabinet at the same height as the C-R tubes and its plane is parallel to and about eight inches back from the front panel. The C-R tubes are supported at the front by a bezel lined with 1/4 inch felt and at the back by a bracket which clamps around the C-R tube and is hung from the top panel. The length of the bracket is adjustable so that the height of the back end of the tube may be aligned with the front. Extension shafts and insulated couplings are employed between the bakelite panel controls and front panel knobs.

The cabinet rack is finished with a smooth black enamel and all panels with a black wrinkle enamel.

C. Specifications

1.	Power Supply	110V., 60 cycle, 1 phase
2.	Power consumption	540 watts
3.	Overall Dimensions	32 1/2 inches W by 24 inches D by 25 1/2 inches H.
4.	Weight	235 pounds

VIII. CAMERA ASSEMBLY

A. General Description

The Dumont type 271-A oscillograph record camera as shown in Figure 13 consists of three major components; the clamp, light hood, and camera proper. The clamp has two adjustment screws which control two diameters, one of which grasps the cathode-ray tube bezel, the other, the light hood. The camera is fixed permanently at the proper distance to insure that the cathode ray tube image will always be in focus. It uses 35 mm film and has a fixed-focus f/3.5 coated lens and simplified shutter with Time, Bulb and

1/30 second exposure positions. The image may be observed through a peep hole at the camera end of the hood and the exposure is made by conventional cable release.

The camera is held on the light hood by a bayonet lock and spring detent so that it can be readily removed for shutter and lens settings, and also for loading and unloading of film spools.

B. Specifications

1.	Lens speed	f/3.5 with diaphragm from f/3.5 to f/16
2.	Shutter speeds	Time, Bulb and 1/30 sec.
3.	Focus	Fixed
4.	Object to image ratio	4.5/1 approx.
5.	Film	35 MM. Super XX
6.	Max. dia. of mounting ring	6 inches
7.	" " " body at center	4 3/4 inches
8.	Overall length	13 1/2 inches
9.	Weight	4 1/2 lbs.

IX. SUGGESTED IMPROVEMENTS

After the equipment had been in use for a while several improvements in the design became apparent. They are as follows:

1. Bring out each control grid of the C-R tubes to a terminal so that external blanking or intensification may be applied.

2. Change position of output and power supply terminals on the V. deflection amplifiers so that they are more accessible.

3. Reverse the mounting of the deflection plate alignment controls and type 6AL5 diodes so that they will be accessible from the rear.

4. Use separate bleeders for each C-R tube gun in the -1500V. supply so that the present heavy current drawing bleeder will not be required.

5. Use a cable connector for termination of control panel wiring at the sweep generator.

6. Use rapid engaging type of fasteners for the panels of the unit in place of the present machine screws.

X. STRAIN TRANSIENT RECORDS

Several strain versus time records have been taken from a typical firing test and are presented here to illustrate the use of this equipment. For the test shown, a single plate of 24ST3 Alclad Aluminum, 0.102 inch thick, was struck by a typical flat end fragment having a mass of 17.22×10^{-4} slugs. The records are shown in Figures 15 and 16 corresponding to 6-type S-R4 strain gages positioned radially from the point of impact. The sinusoidal calibration curve opposite each strain record is used to relate the displacement of the record to units of strain and is obtained by sending a signal of known input voltage and frequency through each channel. This type of calibration was used in obtaining all the records shown. Later work disclosed the need for the more satisfactory type of calibration described on page 21-35. The sinusoidal calibration records shown are scaled to determine the input voltage per unit of displacement. This value is used to relate the units of strain per unit of strain record displacement from known characteristics of the strain gage. For example: The results of scaling the calibration curve corresponding to position A, Figure 15, show that 10.47×10^{-3} volts are required to obtain a deflection on the record of one inch. The voltage applied across the strain gage during impact was 4.25 volts. From previous calibration, the proportionality factor between units of strain and applied voltage for this gage is 3.46. Hence, one inch deflection of the strain record is equal to:

$$\frac{10.47 \times 10^{-3}}{4.25 \times 3.46} = 0.000711 \text{ units of strain.}$$

Time calibration is determined from the known frequency of the input calibration signal. In Figure 15 all calibration signals had a frequency of five (5) kilocycles. Thus, each cycle represents a time duration of 1/5000 = 0.2 milliseconds. Similarly, in Figure 16 each cycle represents a time duration of 1/10,000 = 0.1 milliseconds.

Figure 15 is a record of elastic strain transients only. Figure 16 is a record from a typical firing test resulting in complete penetration. Identical fragments and targets were used in each case. In both records, the high frequency bending strains recorded after passage of the primary strain wave appear to be the result of reflections from the edge of the target. It is interesting to compare the time of penetration with the time required to build up the primary strain wave shown in Figure 16 at point A. For purposes of a qualitative calculation, it may be assumed that the deflection of the target during penetration is equal to or less than that of the same target loaded statically to failure upon a circular support for which the extent of permanent deformation resulting from penetration is the same. The permanent deformation resulting from penetration in this case extended radially from the point of impact to approximately one inch. From static tests conducted previously on identical plates loaded by flat end punches of the same diameter as that of the striking fragment, this amount of deformation corresponds to a deflection of about 0.070 inch. Target thickness was 0.102 inch. Since the average velocity of the fragment was 828 ft./sec., penetration was complete in $\frac{0.070 + 0.102}{828 \times 12} = 0.017$ milliseconds or less. This time should correspond roughly to the time required to build up the primary strain wave at point A of Figure 16 which by direct measurement of the record is approximately 0.03 milliseconds. The fact that this latter time is longer than the calculated time to penetrate is a logical result since point A is located some distance away from the point of impact. It is readily seen that the time required for penetration is only a small portion of the time range covered by the records of Figure 16. It appears likely that some correlation between the time required to build up maximum strains and the time required for penetration can be made from records of strains obtained sufficiently close to the point of impact. Such a correlation would make possible the calculation of target loads as a function of strain rate.

In both cases of elastic impact and penetration the higher strain frequencies are seen to be propagated at higher velocities. This would normally be expected from theory pertaining to the elastic behavior of vibrating plates. As a result it appears that elastic bending is primarily involved in both types of impact.

In Figure 17, maximum and minimum strains are plotted as a function of distance from po t of impact from which it is seen that maximum strains for the case of pen ration are roughly ten times greater than those produced by elastic impact.

In Figures 18 and 19, the radial configuration of the plate is plotted for successive instants. Since the strain gages were spaced at intervals of one inch, there is some doubt as to whether the actual configuration of the plate is accurately represented by the curves drawn through the plotted points. It is possible that higher frequencies would show up by closer spacing of the gages.

MIDWEST RESEARCH INSTITUTE

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P. D. Wickersham

P. D. Wickersham
Research Engineer

APPROVED: M. Goland.

Martin Goland, Chairman
Engineering Mechanics Division

APPENDIX

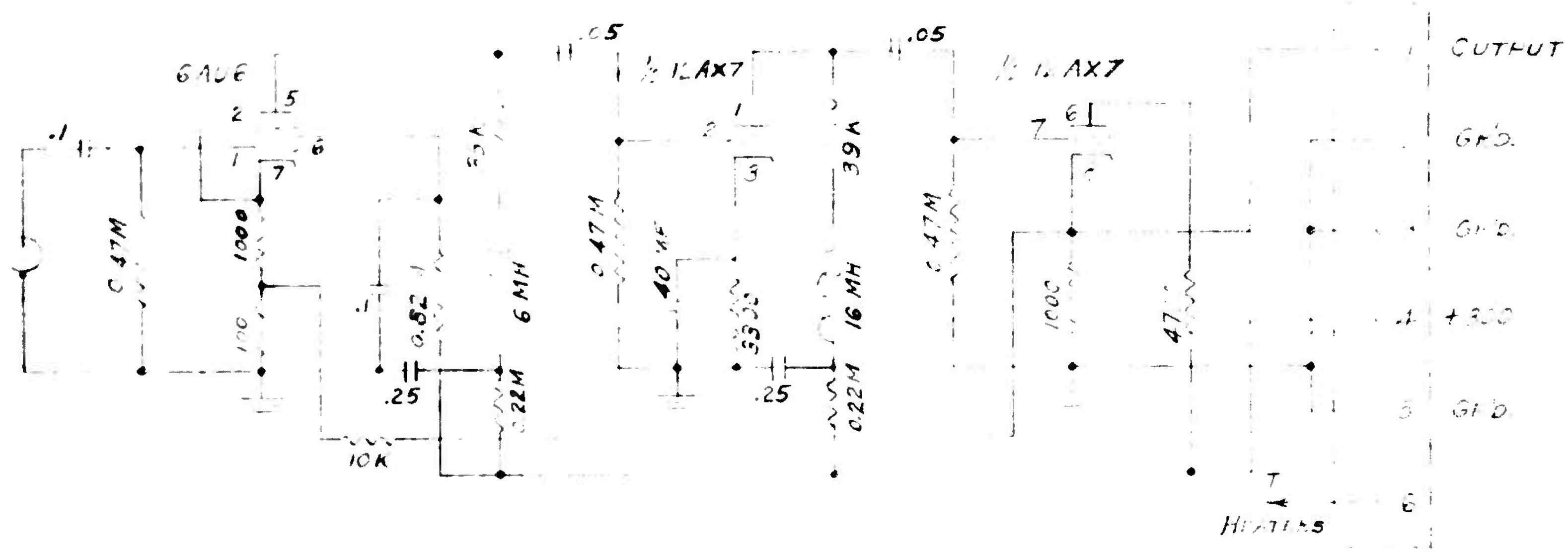

FIG. 1

REV.	BY	DATE

SCHEMATIC
for
PRE-AMPLIFIER

MIDWEST RESEARCH INSTITUTE
KANSAS CITY 2, MISSOURI

PROJECT NO. W.O. 15

DRAWING NO

SCALE NONE

DRAWN DATE

CHCKD DATE

APPR. DATE

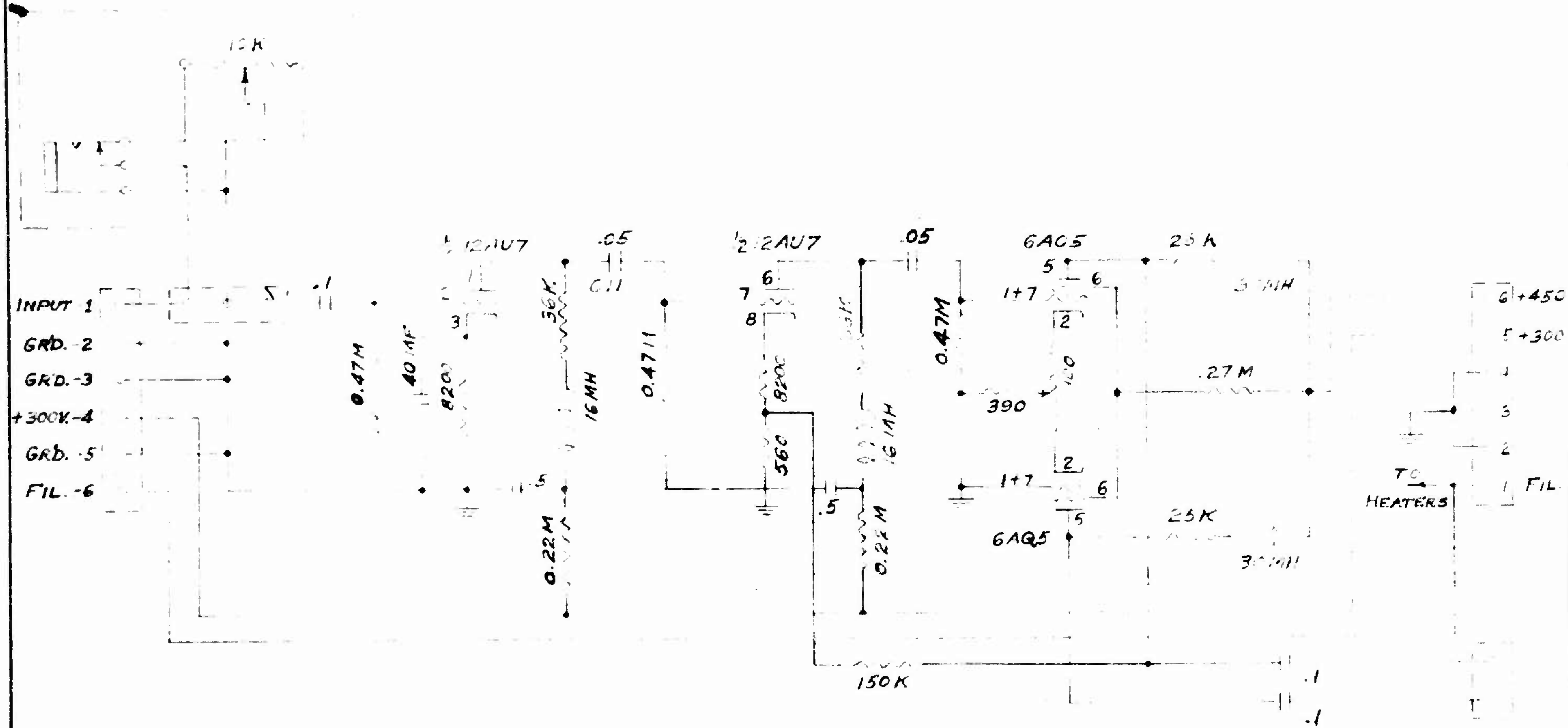

FIG. 2

REV.	BY	DATE

SCHEMATIC
FOR
MAIN DEFLECTION AMPLIFIER

PROJECT NO. W.O. 15-50

DRAWING NO. 2-15-5-21

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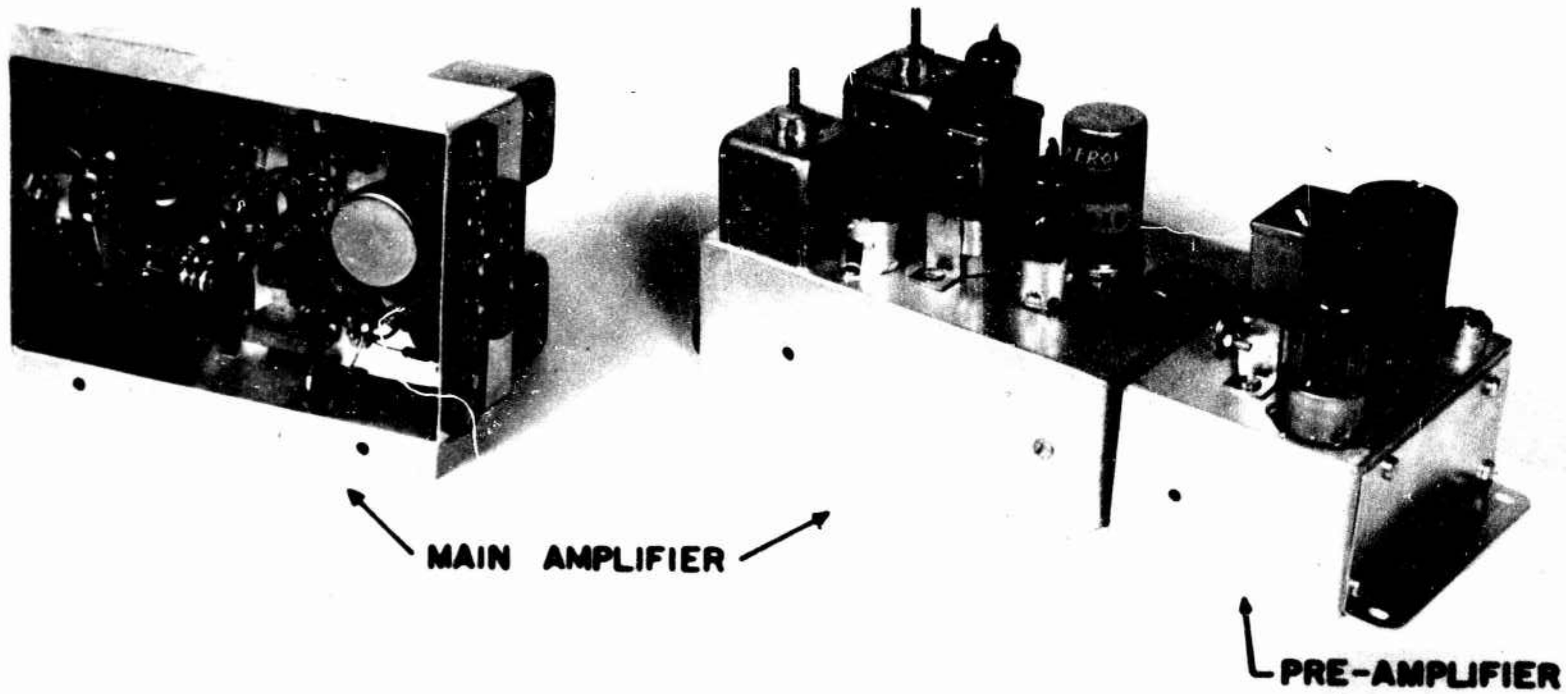

RESTRICTED

Fig. 3 Vertical Deflection Amplifier

RESTRICTED

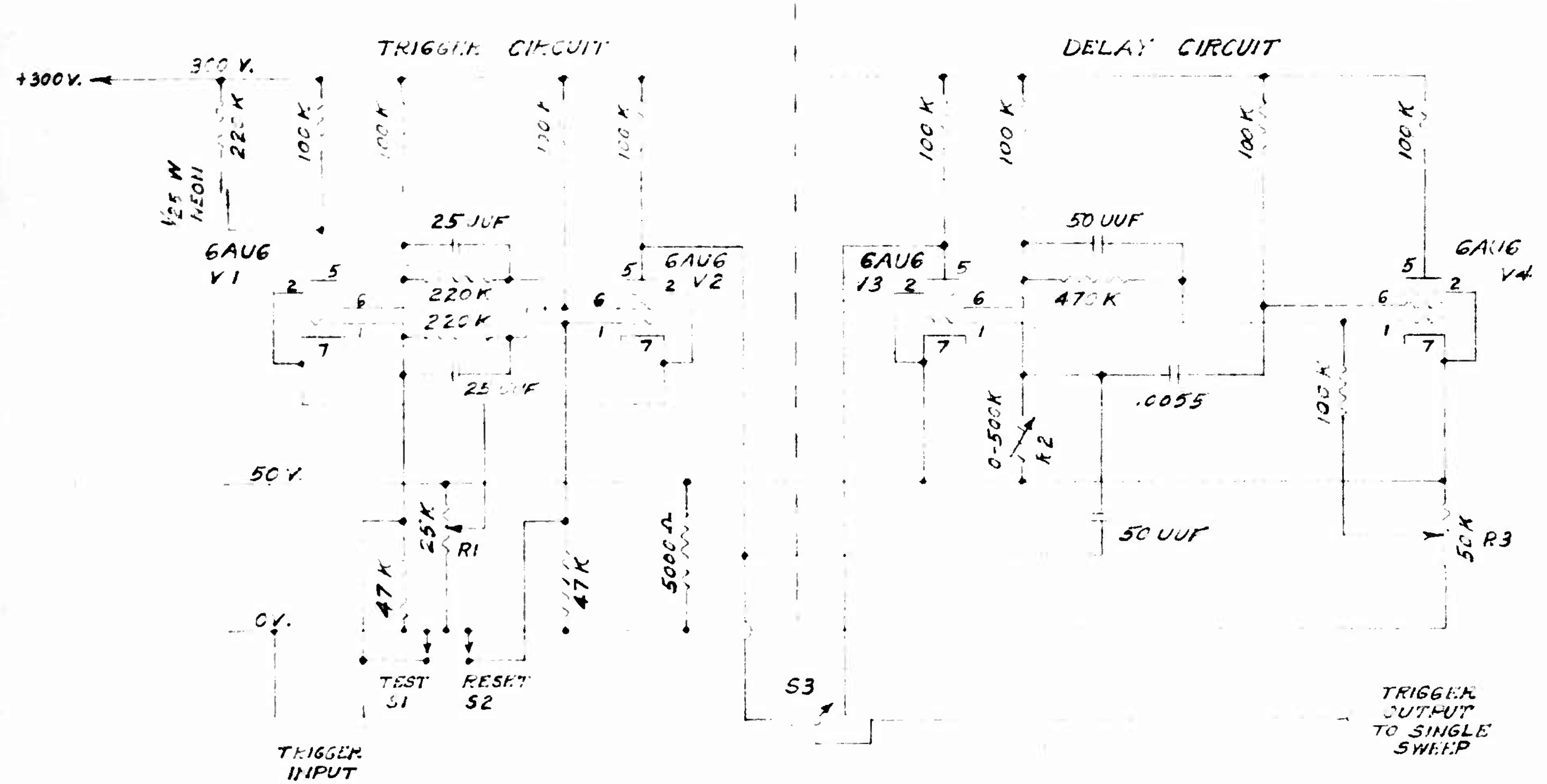

FIG. 4

REV.	BY	DATE

SCHEMATIC FOR TRIGGER CIRCUIT & DELAY CIRCUIT

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PROJECT NO. W.O. 1500

DRAWING NO. 2-548-E-22

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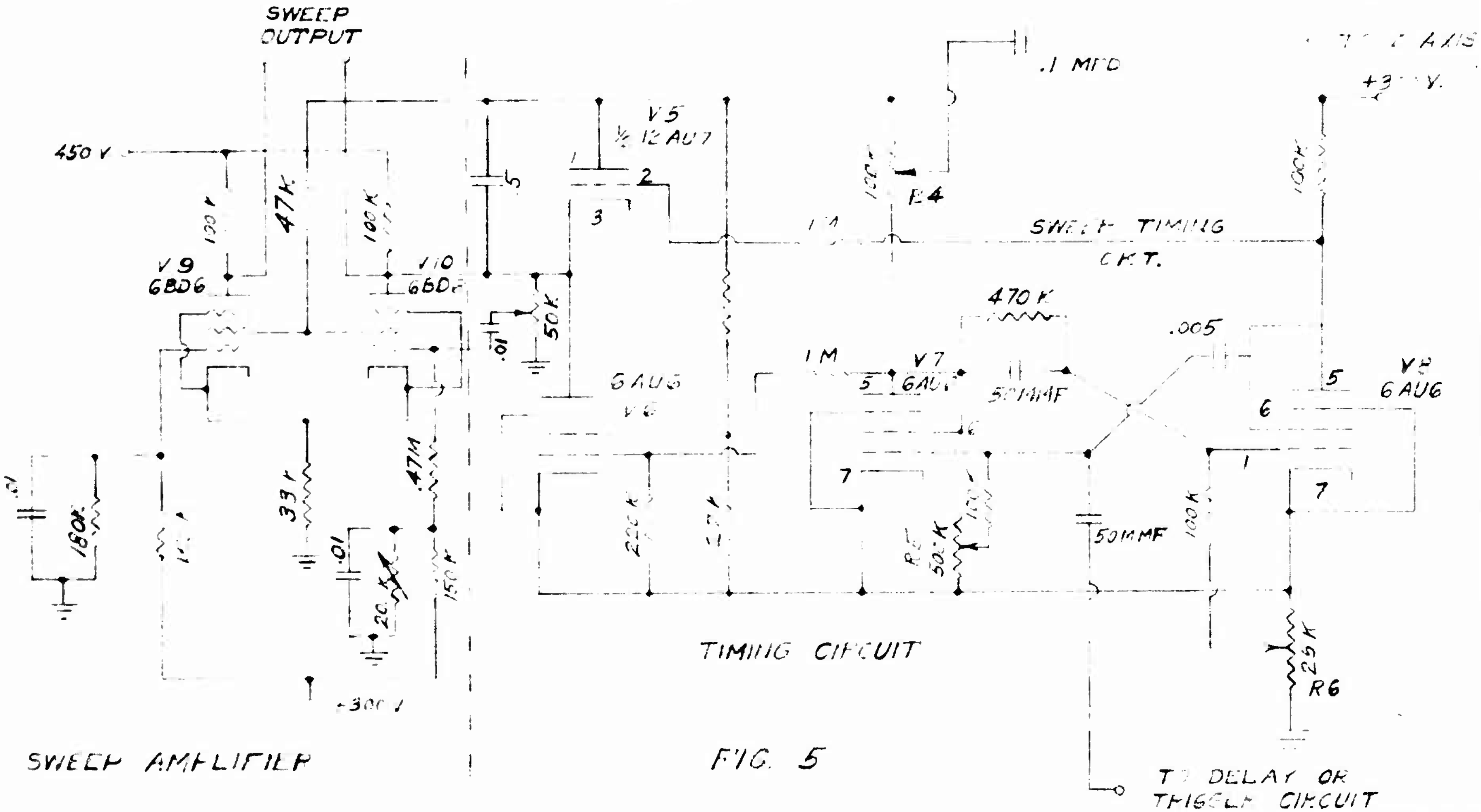

FIG. 5

REV.	BY	DATE

SCHEMATIC
FOR
SWEEP AMPLIFIER & TIMING CIRCUIT

MIDWEST RESEARCH INSTITUTE
KANSAS CITY 2, MISSOURI

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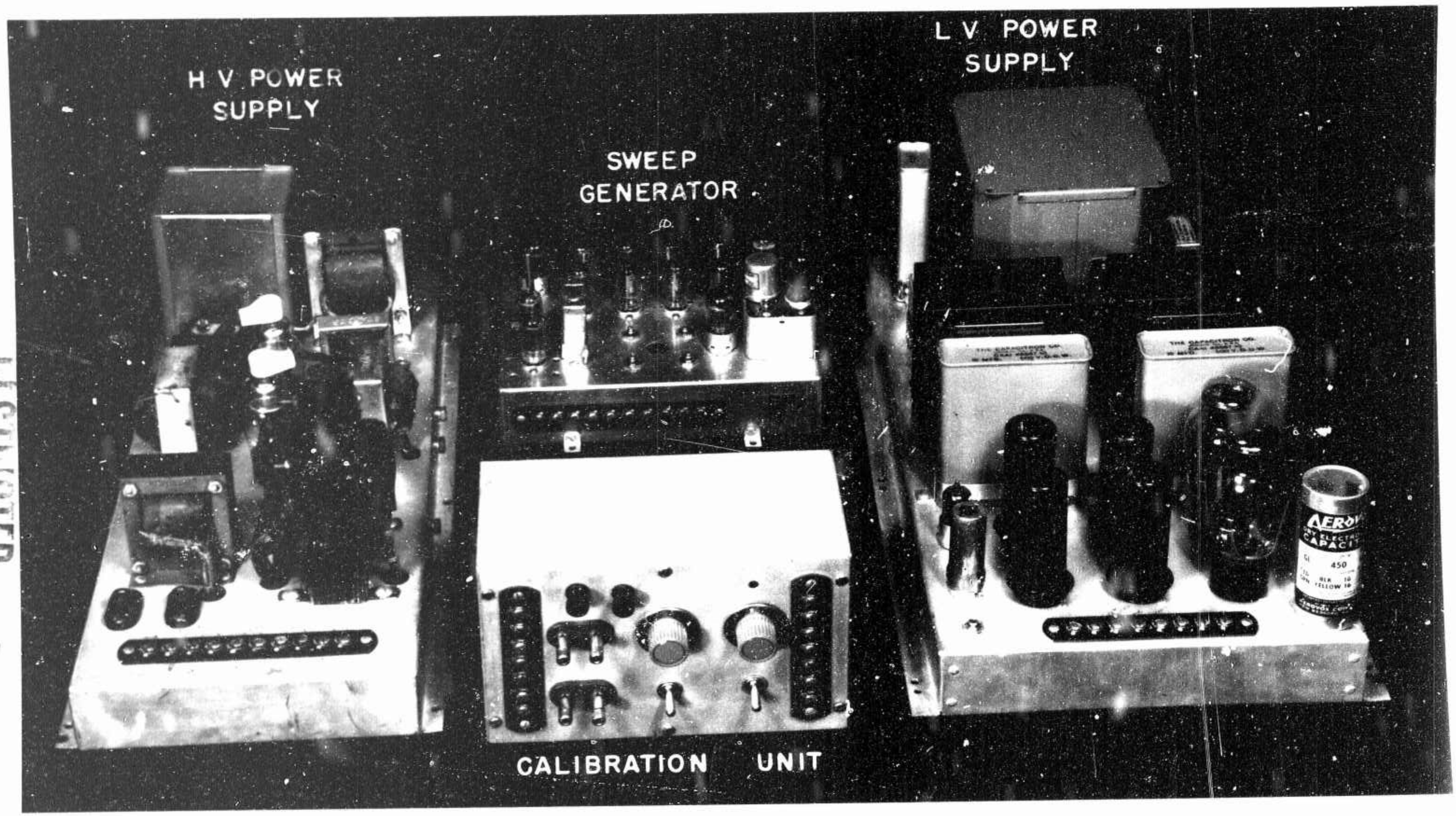


RESTRICTED

Fig. [illegible] Units Mounted on Lower Shelf

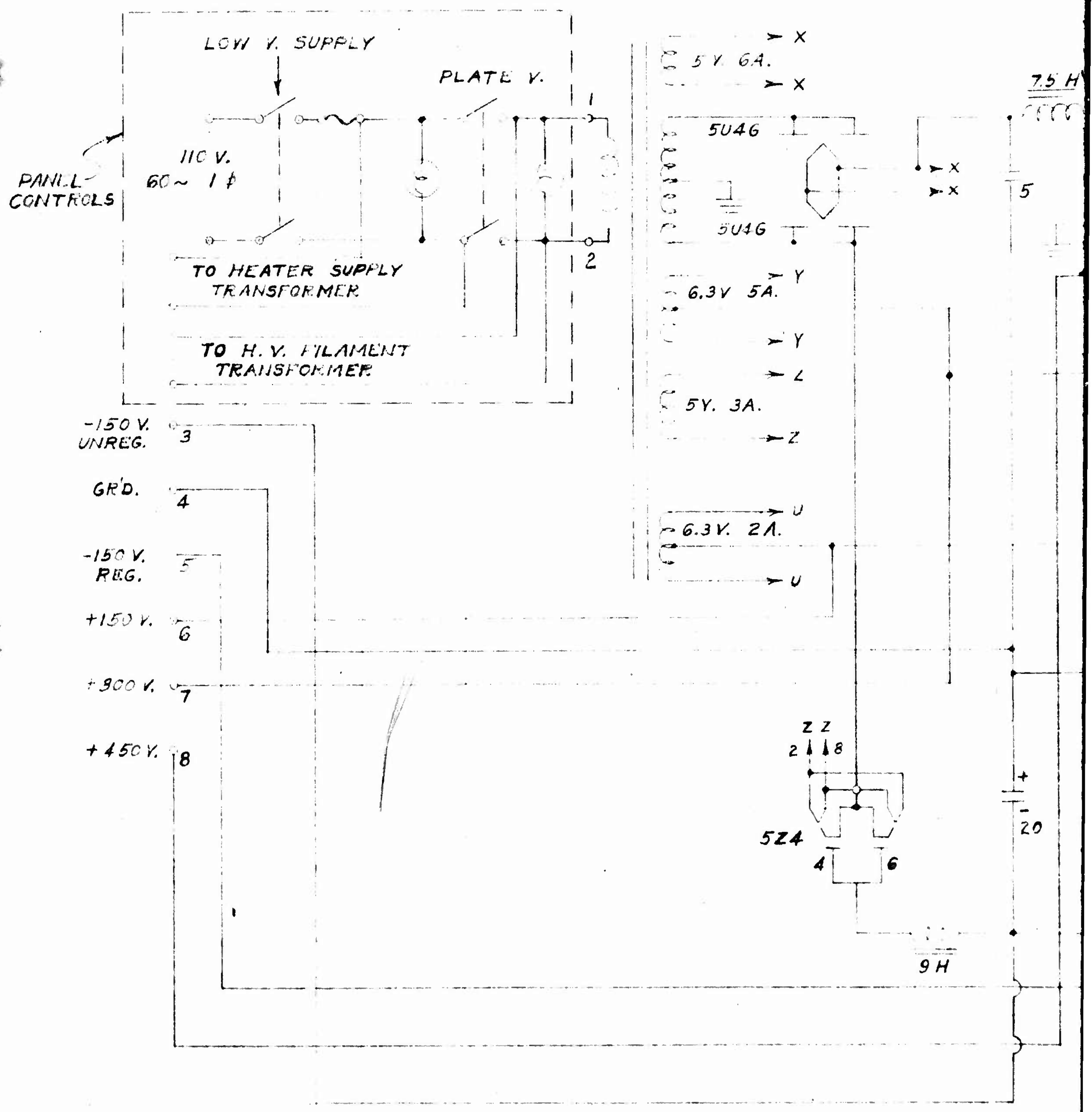
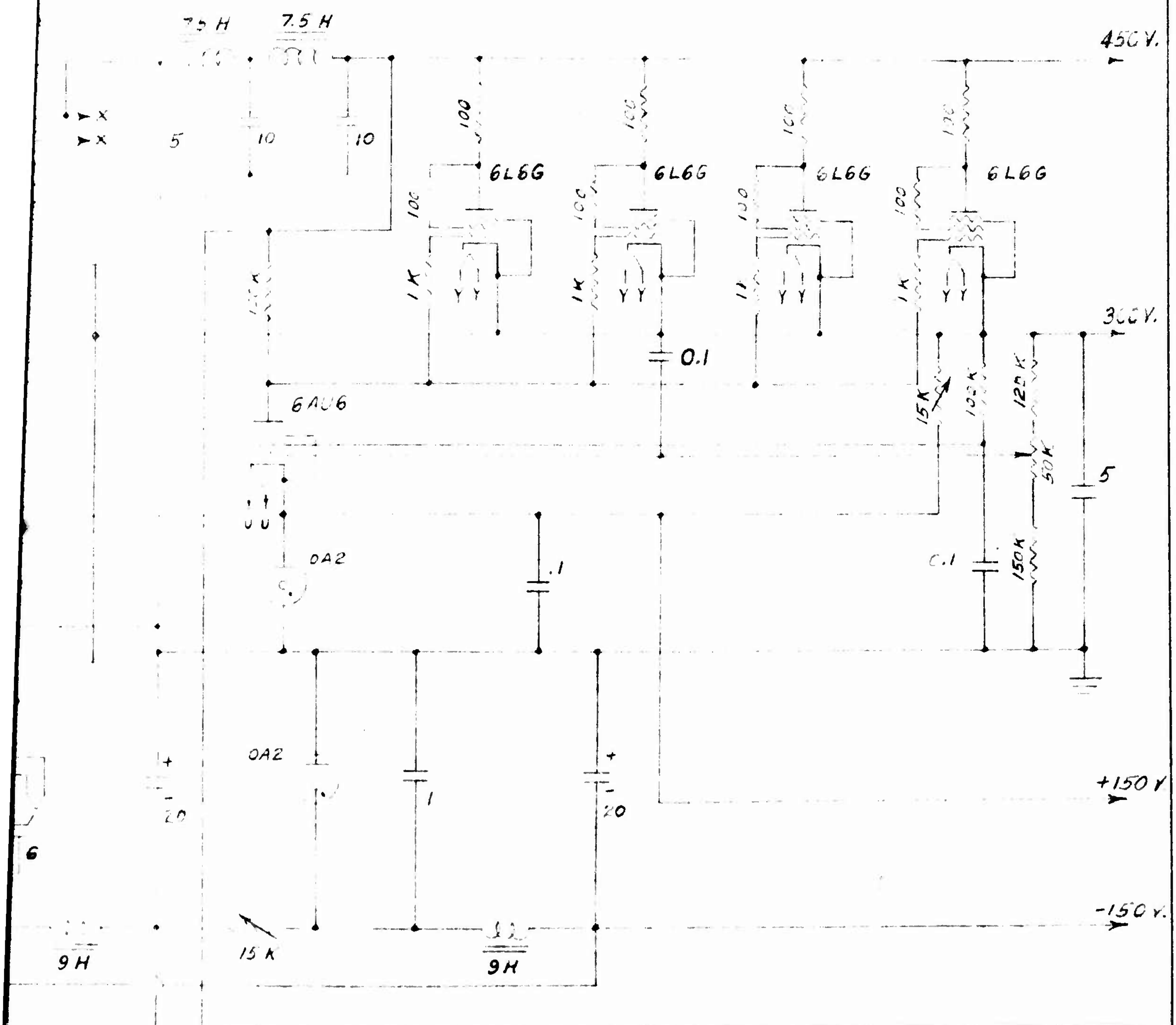
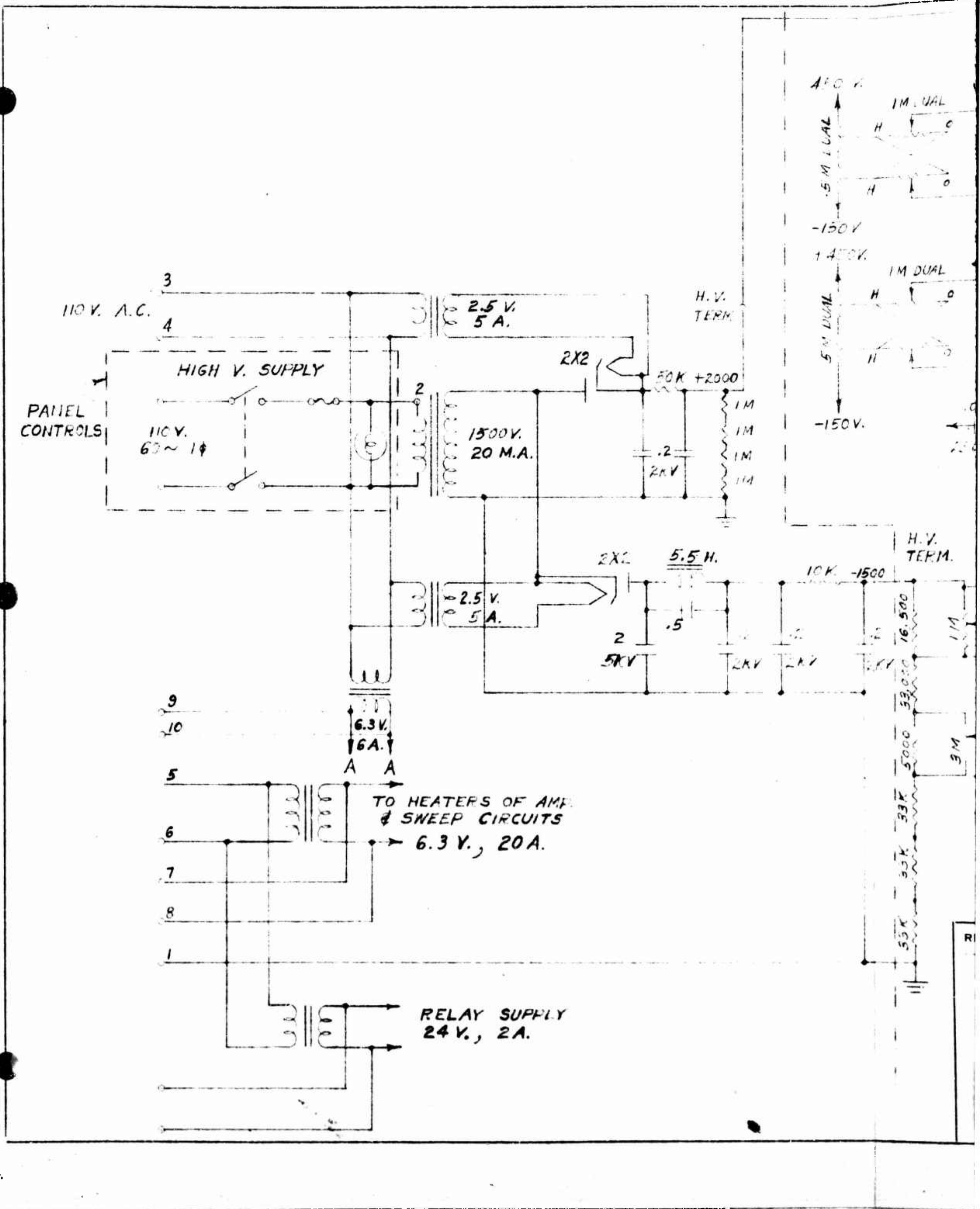

LOW V. SUPPLY
PLATE V.
PANEL CONTROLS
110 V.
60~ 1 φ
TO HEATER SUPPLY TRANSFORMER
TO H.V. FILAMENT TRANSFORMER
1
2
5 V. 6A.
X
5U4G
5U4G
6.3 V 5A.
Y
Z
5 V. 3A.
6.3 V. 2A.
U
7.5 H
5
-150 V. UNREG.
3
GR'D.
4
-150 V. REG.
5
+150 V.
6
+300 V.
7
+450 V.
8
Z Z
2 8
5Z4
4 6
20
9 H

FIG. 7



REV.	BY	DATE	SCHEMATIC FOR LOW VOLTAGE POWER SUPPLY	PROJECT NO. W.O. 1350	DRAWN DATE 9-10-45	CHCKD. DATE	APPR. DATE
				DRAWING NO. 25-46E-22			
			MIDWEST RESEARCH INSTITUTE KANSAS CITY 2, MISSOURI	SCALE NONE			

RESTRICTED



110 V. A.C.
HIGH V. SUPPLY
PANEL CONTROLS
110 V. 60~ 1¢
2.5 V. 5 A.
1500 V. 20 M.A.
2X2
50K +2000
1M
.2 2KV
H.V. TERM.
1M DUAL
5M DUAL
-150 V.
2X2
5.5 H.
10K -1500
.5
2 5KV
2KV
2.5 V. 5 A.
16,500
33,000
5000
33K
3M
6.3 V. 6A.
TO HEATERS OF AMP. & SWEEP CIRCUITS 6.3 V., 20 A.
RELAY SUPPLY 24 V., 2A.

RESTRICTED

2

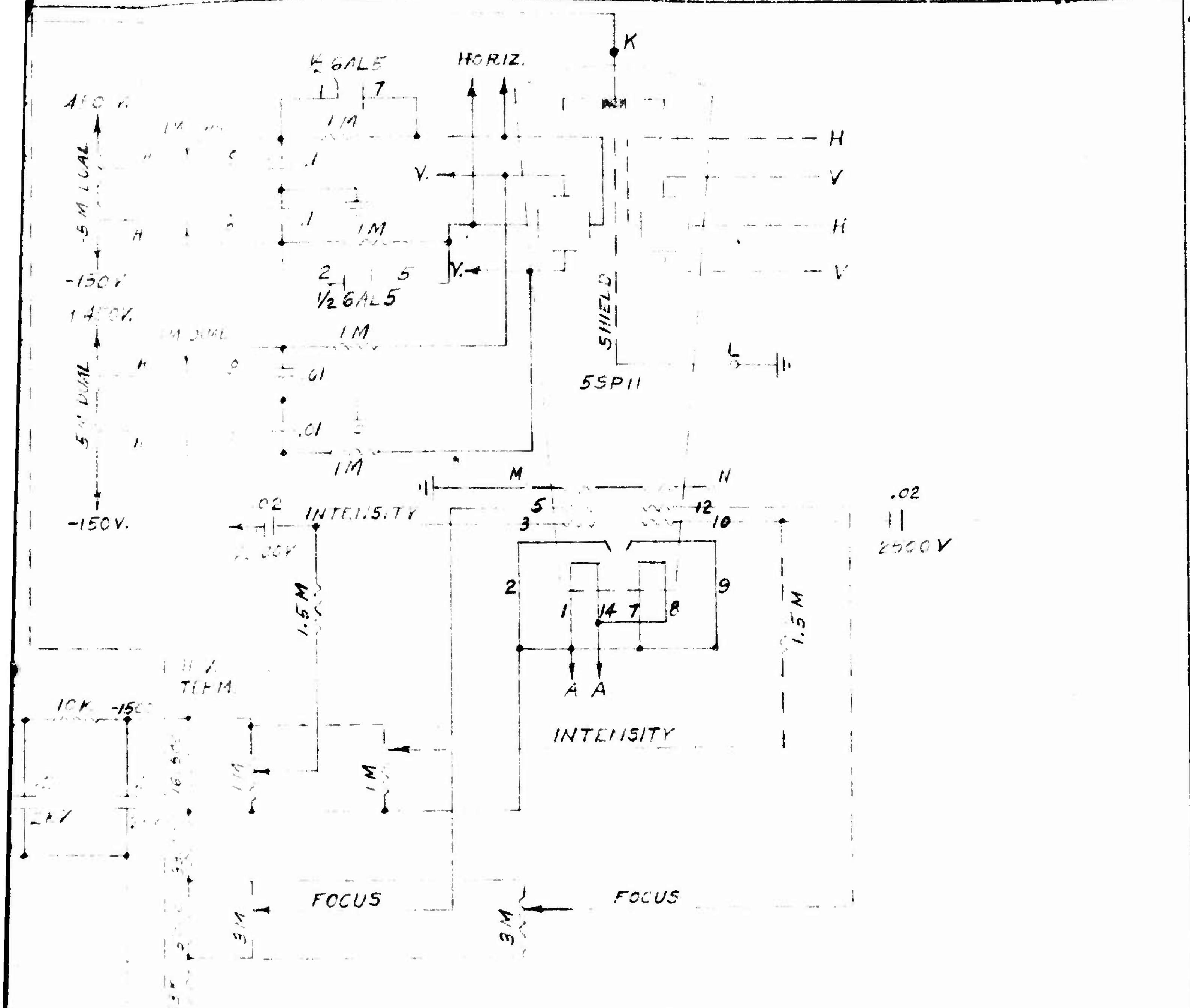
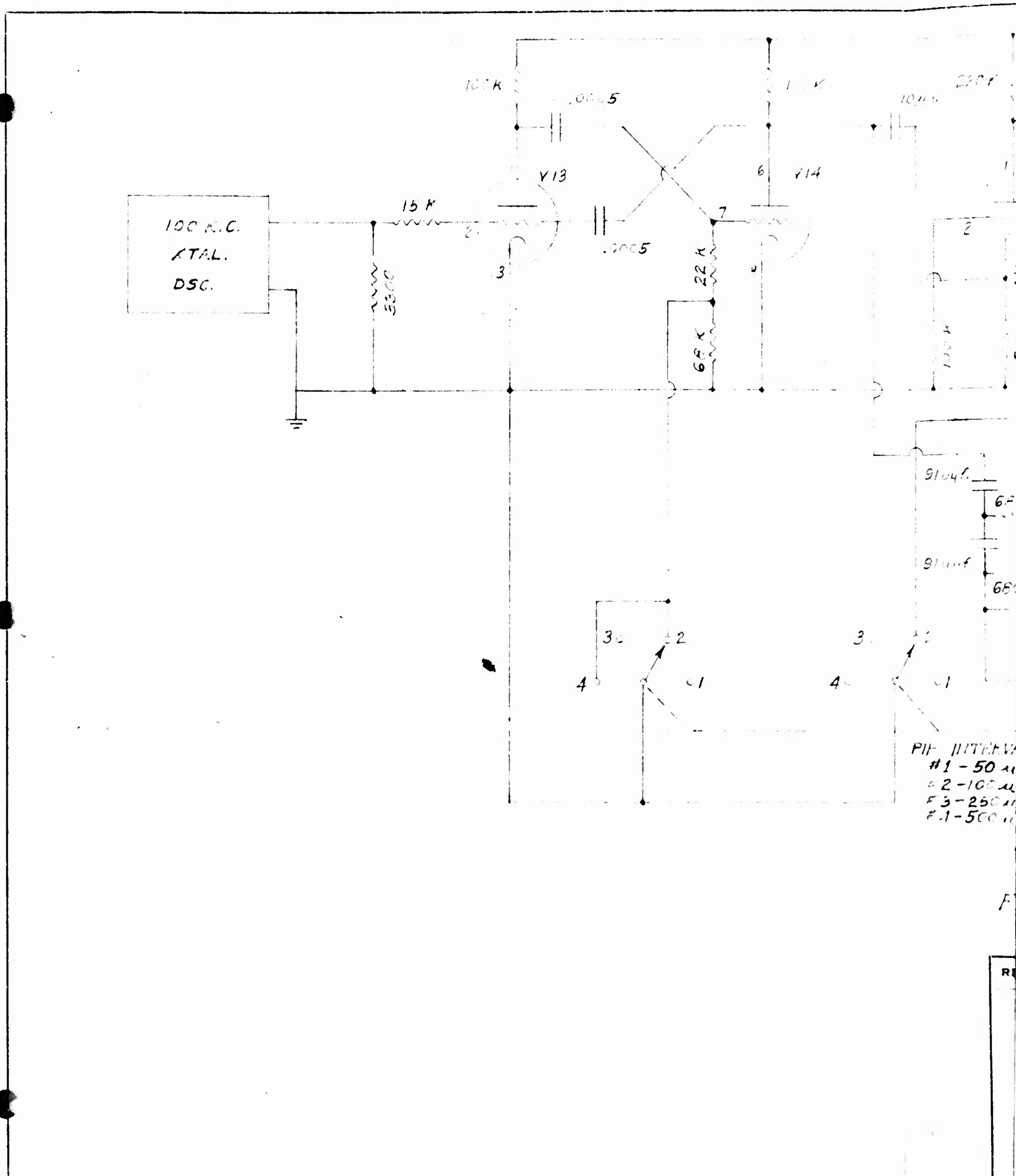


FIG. 8

REV.	BY	DATE		PROJECT NO.	
			SCHEMATIC FOR HIGH VOLTAGE POWER SUPPLY & C-R TUBE CONTROLS	W.O. 1880	DRAWN DATE 9-11-48
				DRAWING NO. 25 48E-25	CHCKD. DATE
			MIDWEST RESEARCH INSTITUTE KANSAS CITY 2, MISSOURI	SCALE NONE	APPR. DATE

RESTRICTED



100 K.C.
XTAL.
OSC.
15 K
3300
100K
.0005
V13
.0005
V14
22 K
68 K
91 uuf
91 uuf
PIP INTERVA
#1 - 50
#2 - 100
#3 - 250
#4 - 500

RESTRICTED

2

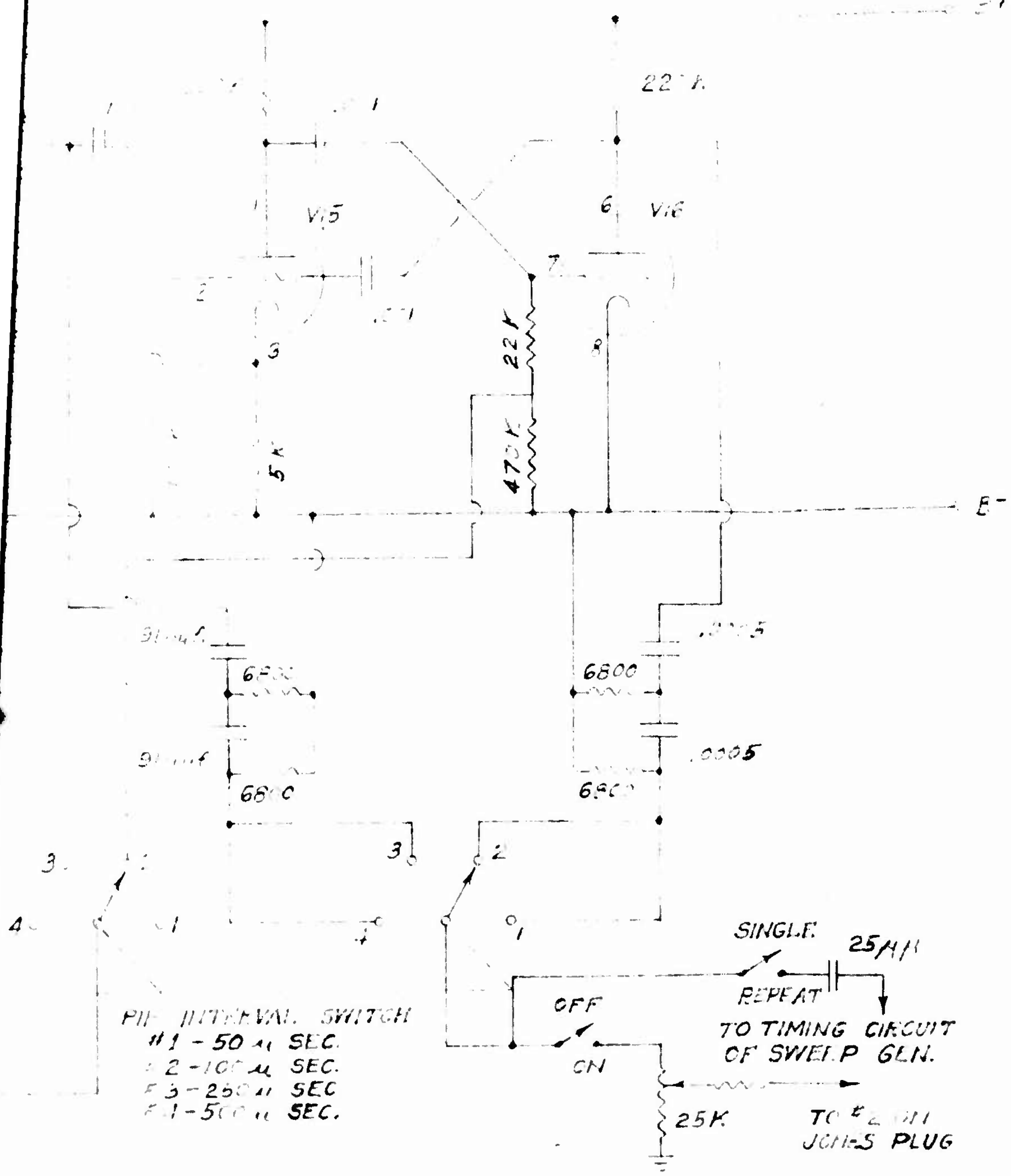
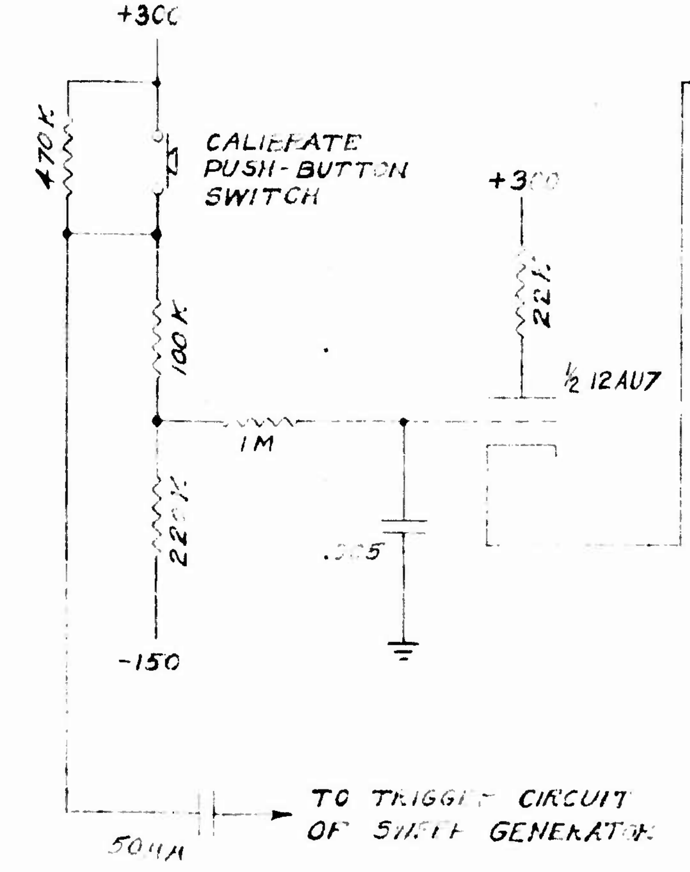


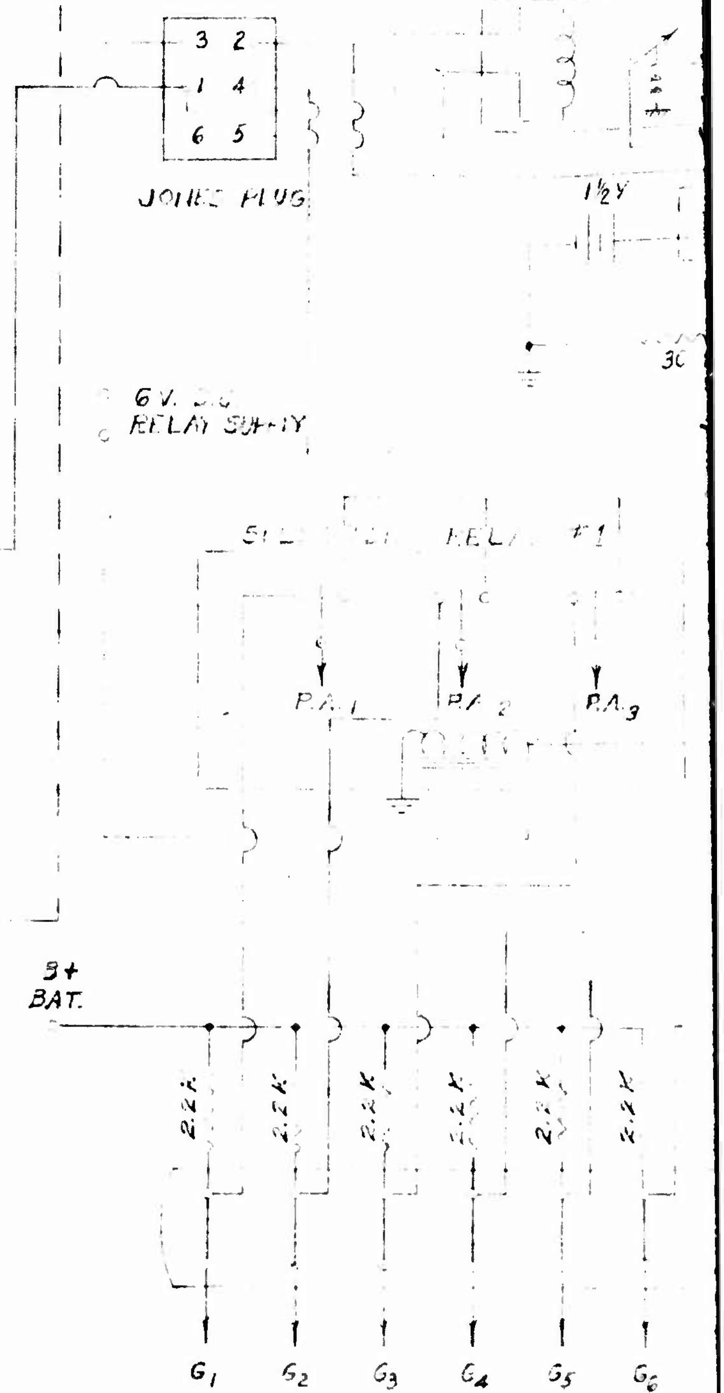
FIG. 9

REV.	BY	DATE		PROJECT NO.	
			SCHEMATIC FOR CALIBRATION PIP GENERATOR	W.O. 188C	DATE
				DRAWING NO. 2-548-E-27	DATE
			MIDWEST RESEARCH INSTITUTE KANSAS CITY 2, MISSOURI	SCALE NONE	DRAWN / CHCKD / APPR

RESTRICTED



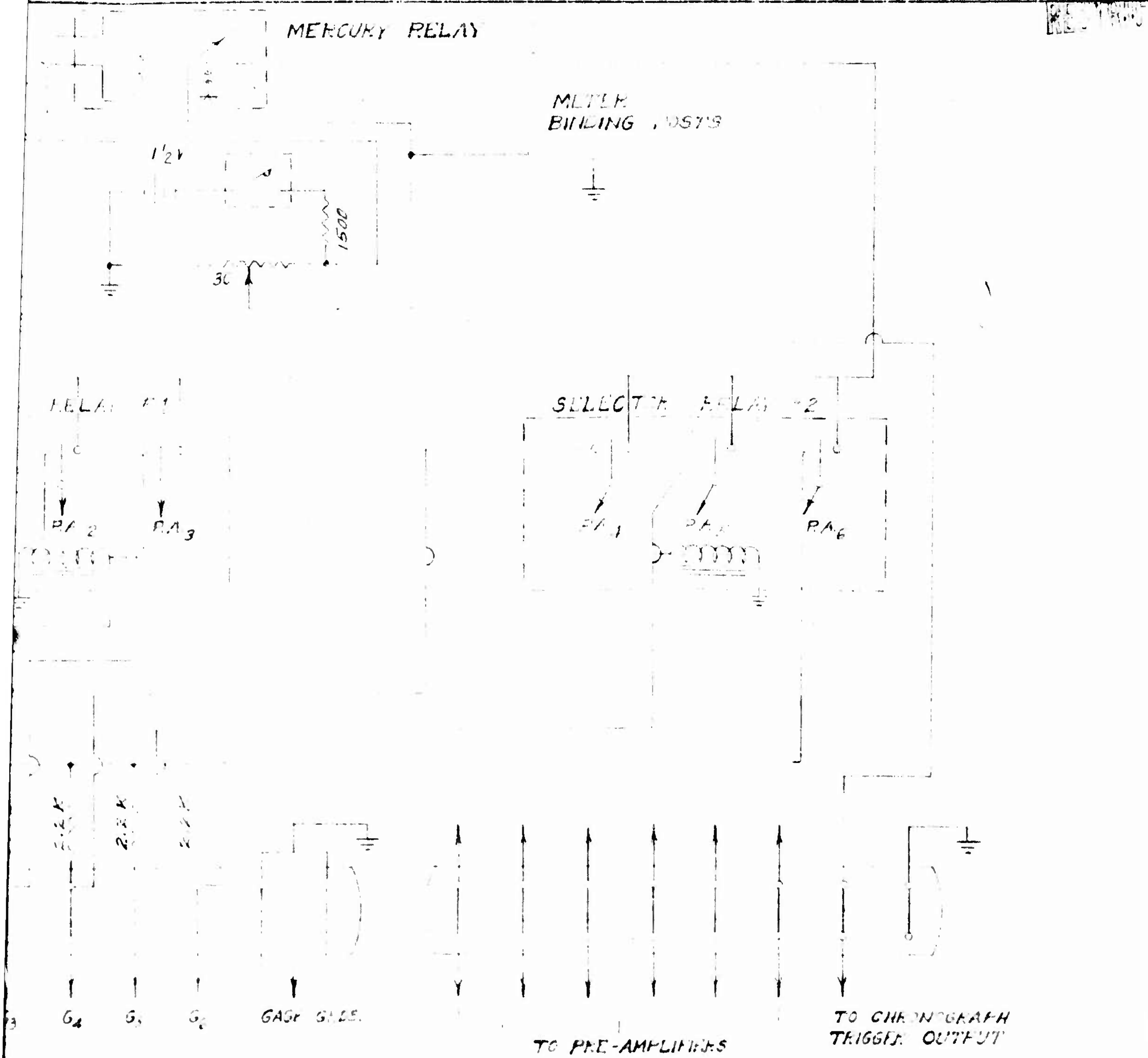
CALIBRATION - TRIGGER CIRCUIT
(LOCATED ON SWELF GEN. CHASSIS)



CALIBRATION - REMOTE CONTROL

FIG. 10

2

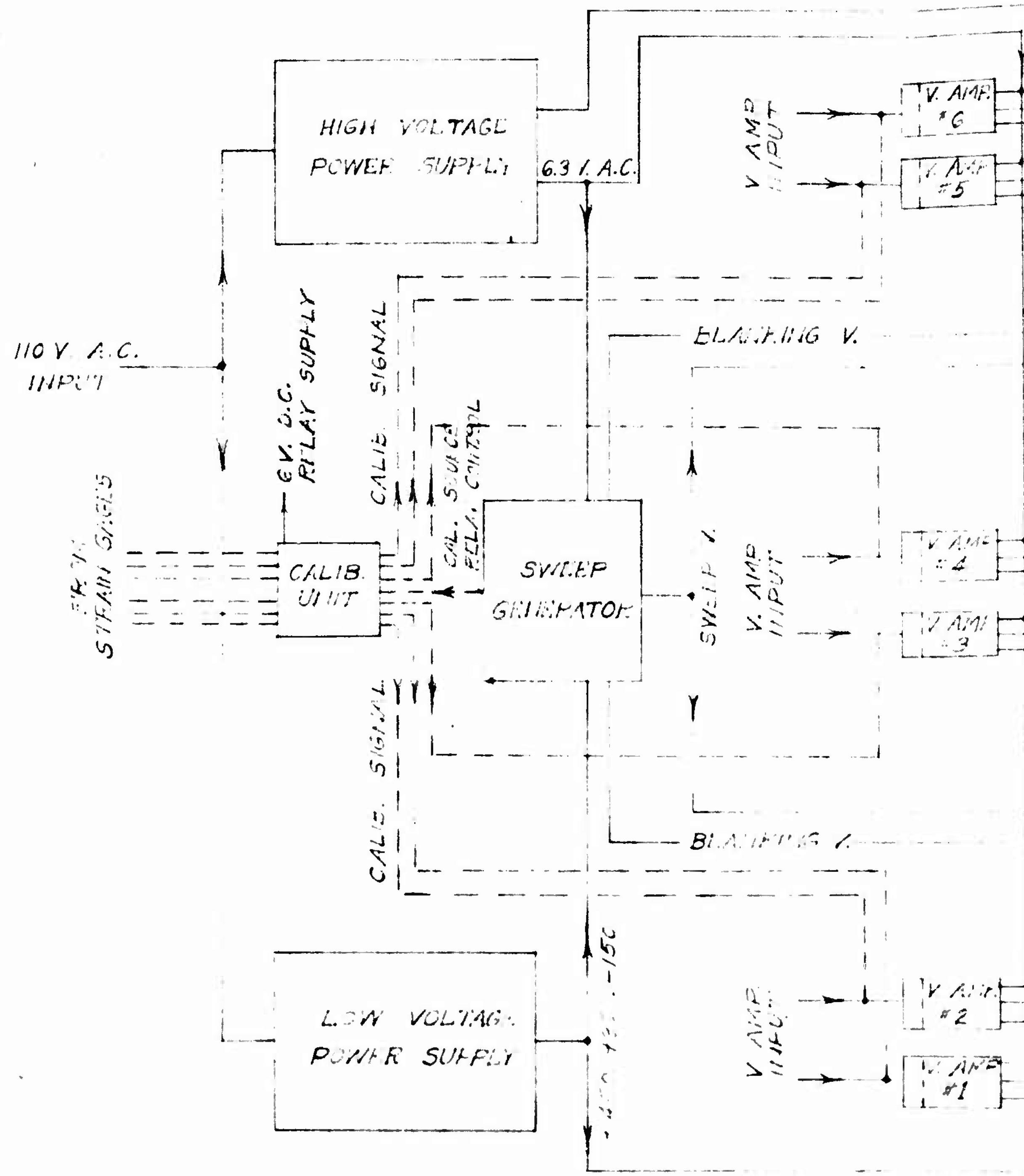


REMOTE CONTROL

FIG. 10

REV.	BY	DATE		PROJECT NO.			
			SCHEMATIC FOR CALIBRATION CIRCUITS	DRAWING NO. 2-548 F-28	DRAWN	CHCKD.	APPR.
			MIDWEST RESEARCH INSTITUTE KANSAS CITY 2, MISSOURI	SCALE None	DATE 10/11/48	DATE	DATE

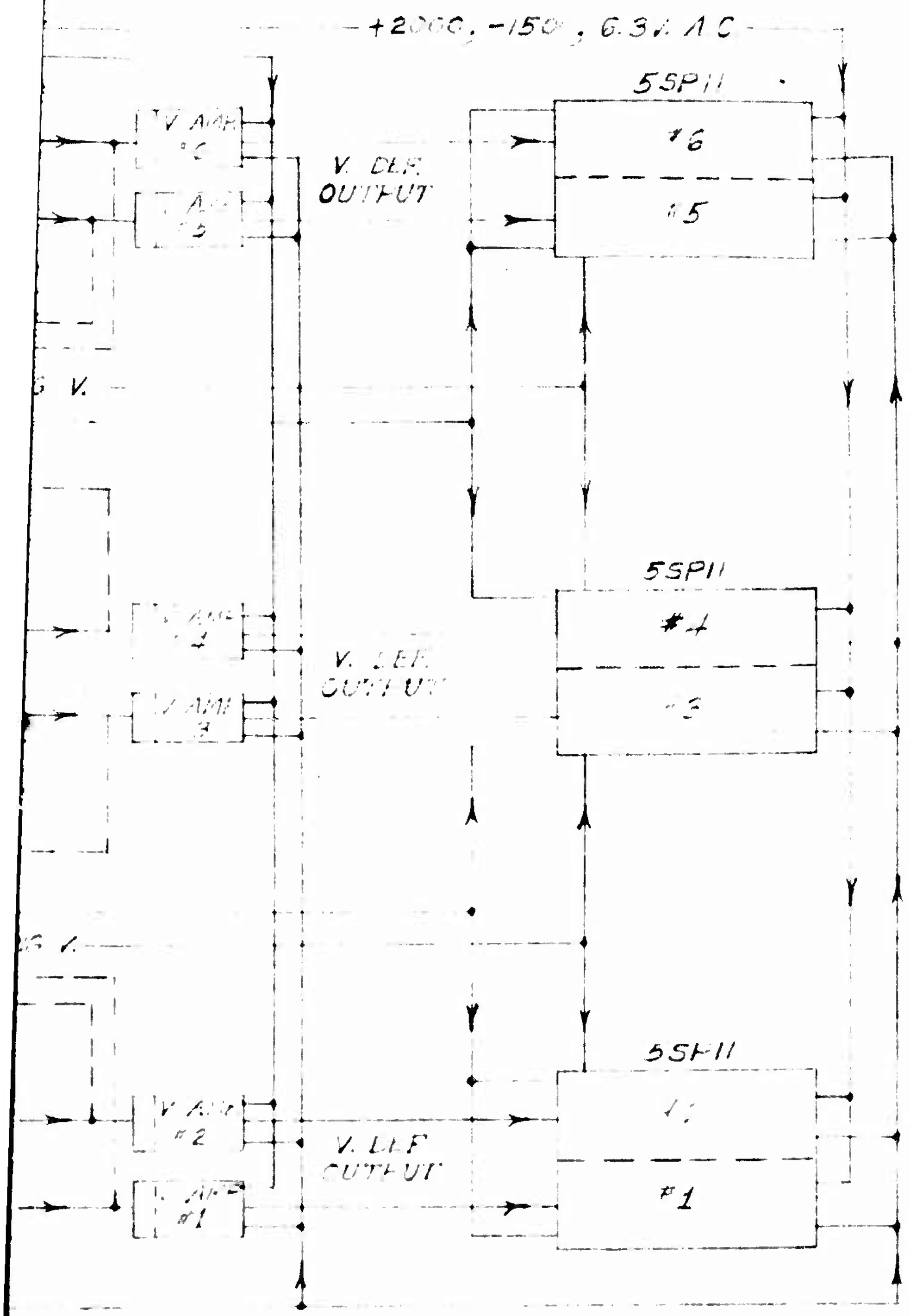
RESTRICTED



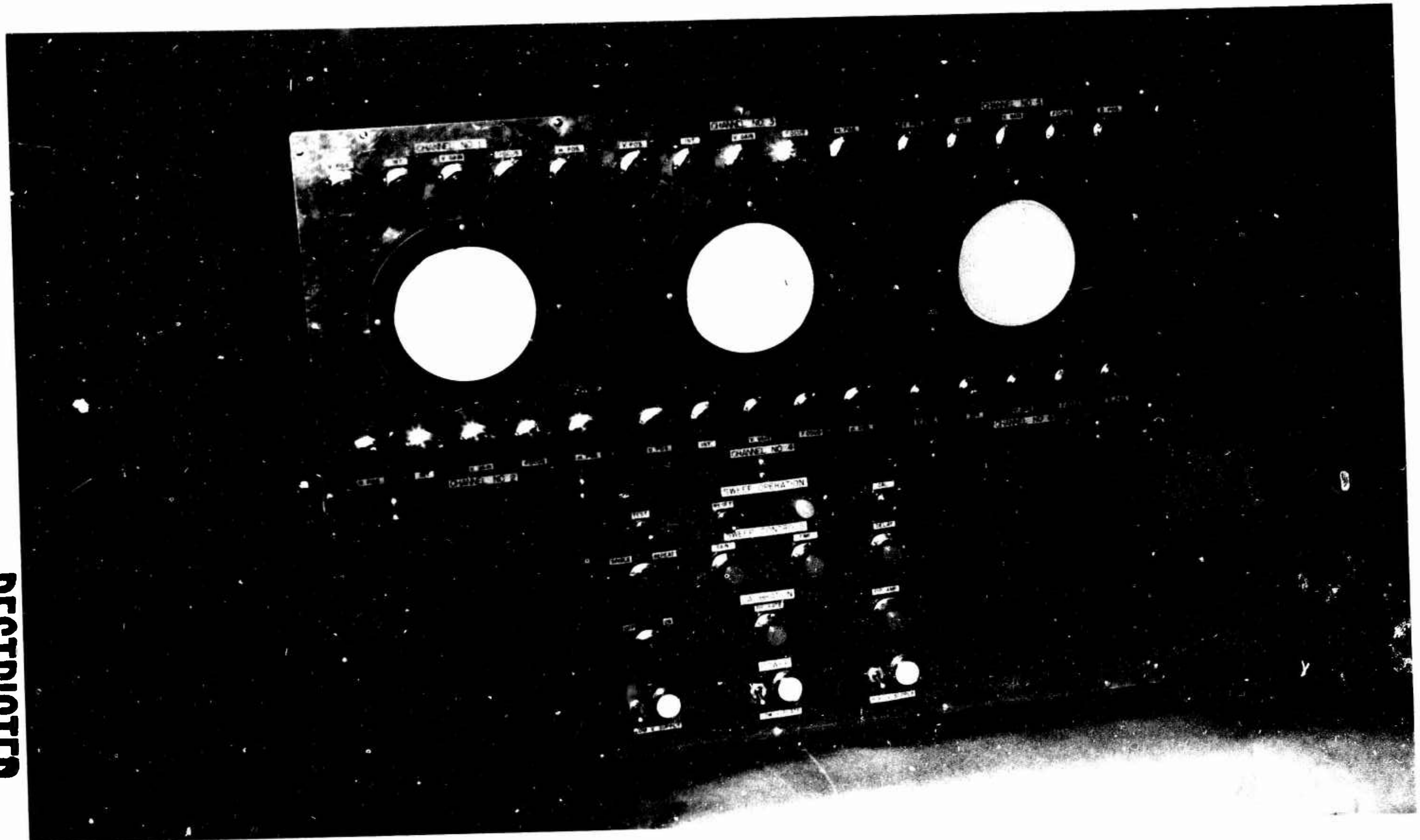
HIGH VOLTAGE POWER SUPPLY
6.3 V. A.C.
V. AMP INPUT
V. AMP #6
V. AMP #5
BLANKING V.
110 V. A.C. INPUT
6 V. D.C. RELAY SUPPLY
CALIB. SIGNAL
CAL. SOURCE RELAY CONTROL
CALIB. UNIT
SWEEP GENERATOR
SWEEP V.
V. AMP INPUT
V. AMP #4
V. AMP #3
CALIB. SIGNAL
LOW VOLTAGE POWER SUPPLY
-150
V. AMP INPUT
V. AMP #2
V. AMP #1

FIG. 11

2



REV.	BY	DATE		PROJECT NO.			
			FLOCK DIAGRAM FOR 6 CHANNEL TRANSIENT RECORDER	W.O. 1880	DATE 10-6-48	DATE	DATE
				DRAWING NO. 2 SAB F-26			
			MIDWEST RESEARCH INSTITUTE KANSAS CITY 2, MISSOURI	SCALE NONE	DRAWN	CHCKD.	APPR.



RESTRICTED

Fig. 12 (a) Front View

RESTRICTED

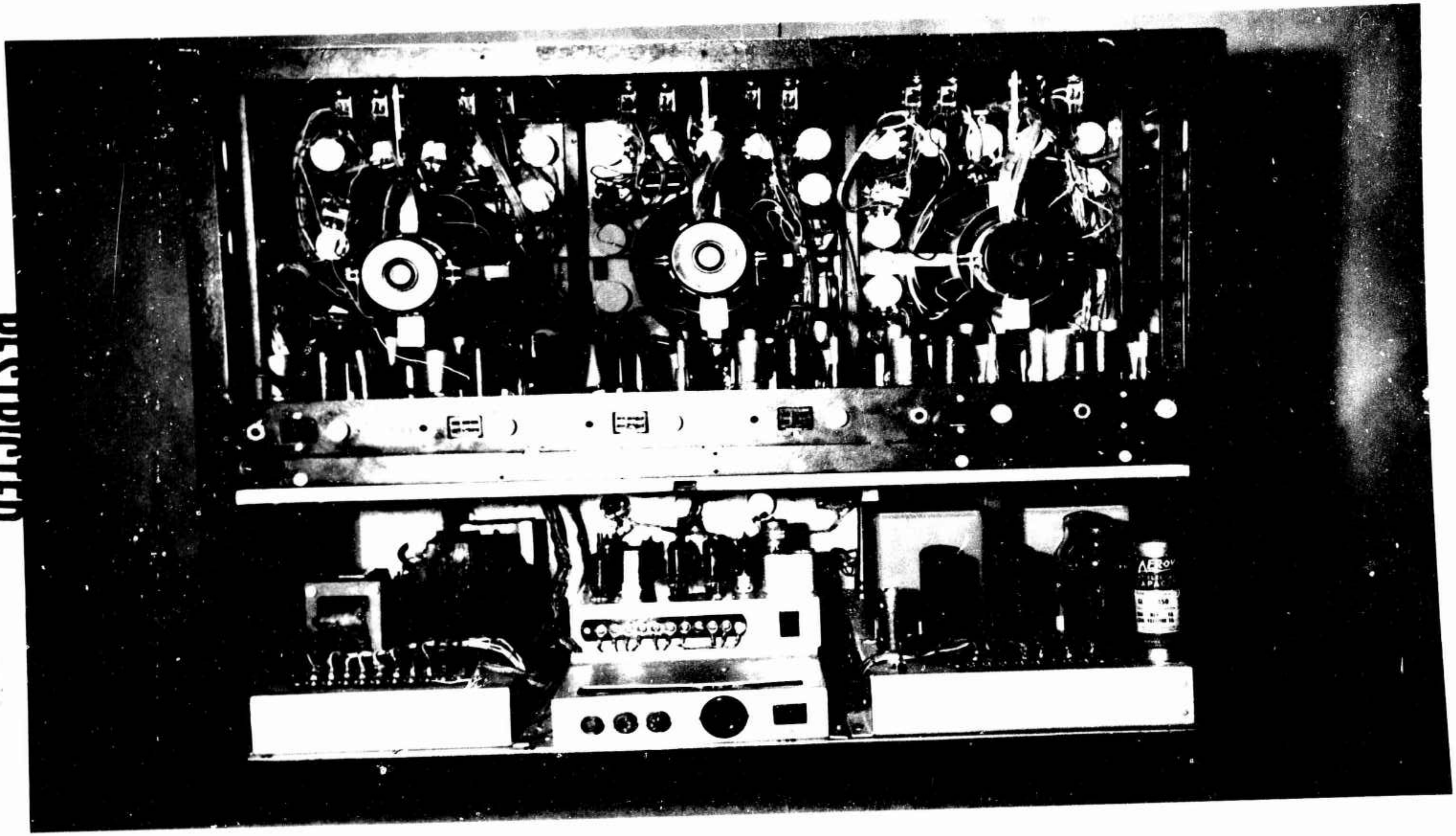


Fig. 12 (b) Rear View (Panels Removed)

Fig. 12 (c) Rear View

RESTRICTED

RESTRICTED

RESTRICTED

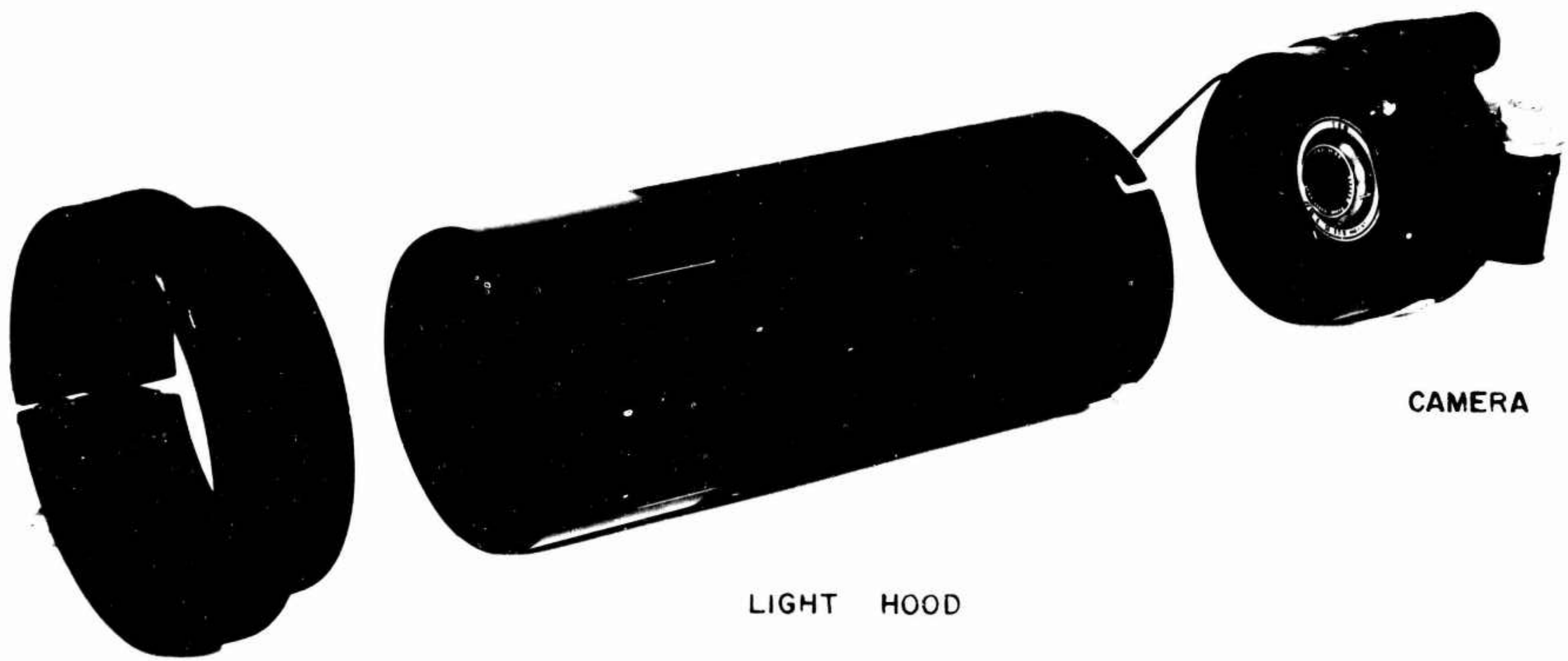


Fig. 13 Camera Assembly

RESTRICTED

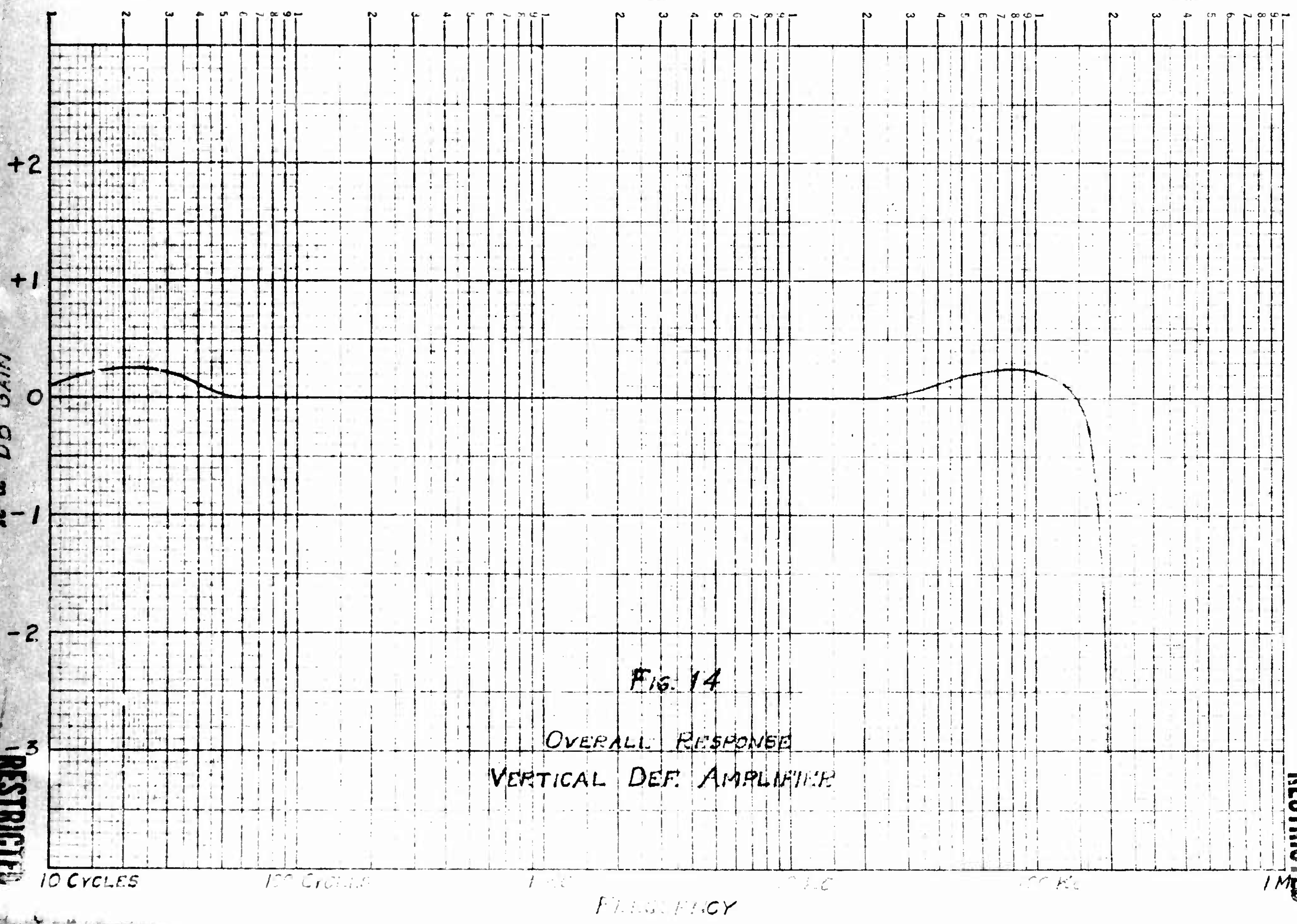
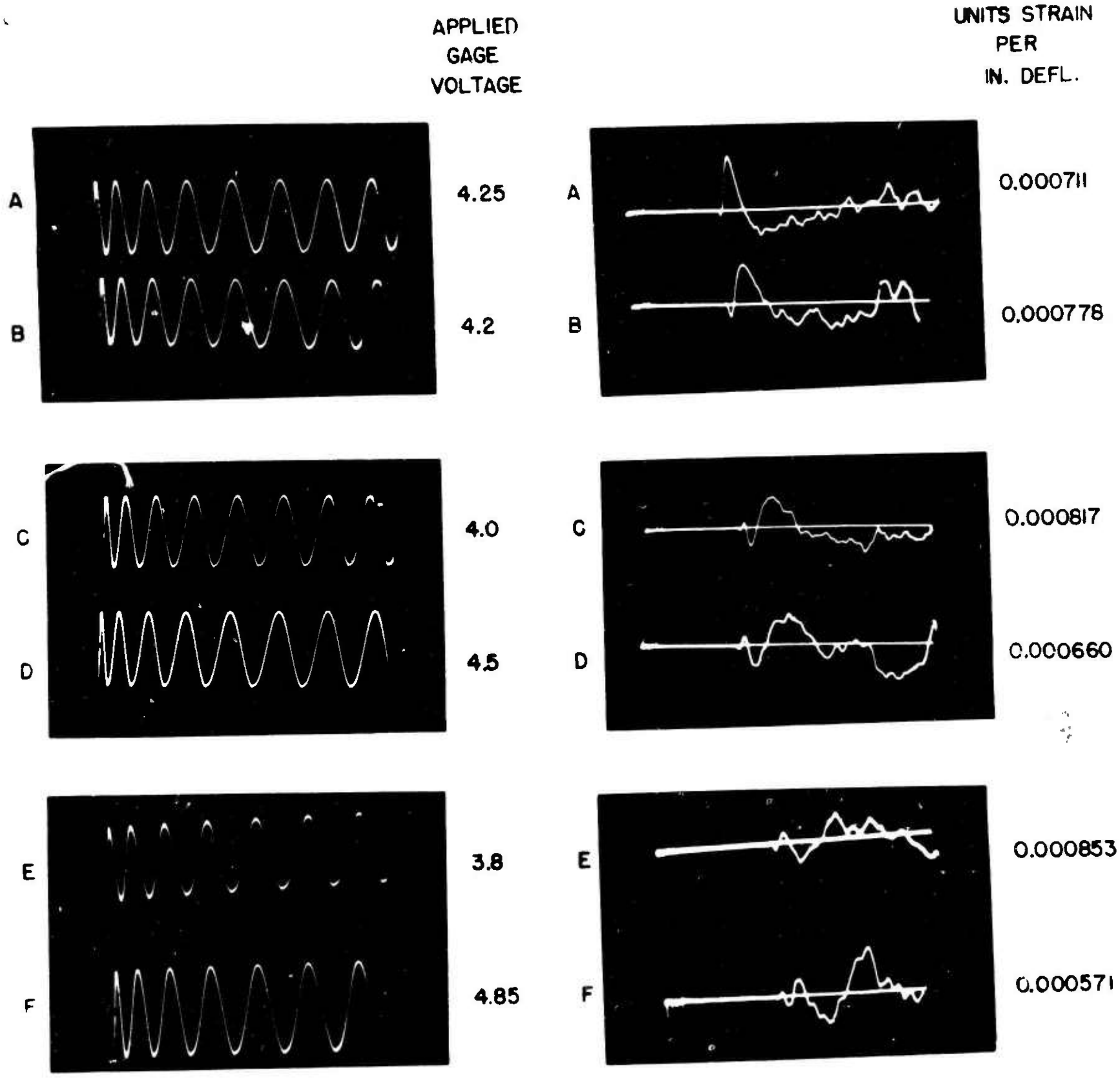


FIG. 14

OVERALL RESPONSE
VERTICAL DEF. AMPLIFIER

21-35

RESTRICTED



CALIBRATION

2 MILLIVOLTS @ 5 KC
GAGE FACTOR = 3.46

ELASTIC IMPACT

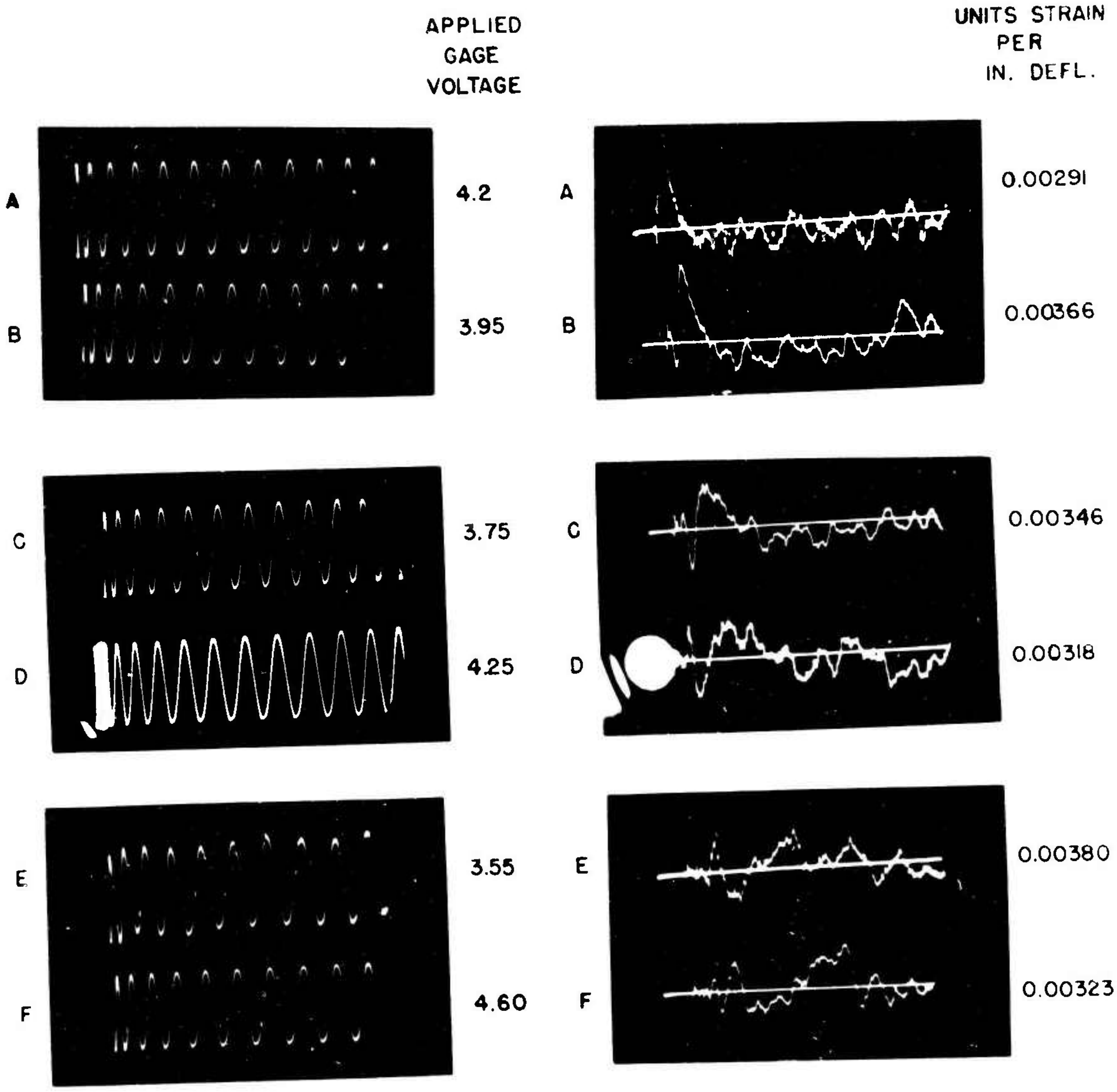
V_1 = 17.6 FT./SEC.
M = 17.22 X 10^{-4} SLUGS
h = 0.102 IN.
p = 1.57 IN.

STRAIN TRANSIENTS IN 24ST ALCLAD ALUMINUM PLATE AS A FUNCTION OF THE DISTANCE FROM POINT OF IMPACT.

r IS DISTANCE FROM POINT OF IMPACT
h IS THE THICKNESS OF THE PLATE.

POINT	r/h	POINT	r/h	POINT	r/h
A	15	C	34	E	54
B	25	D	44	F	64

FIG. 15



CALIBRATION

10 MILLIVOLTS @ 10KC
GAGE FACTOR = 3.46

PENETRATION

V_1 = 866 FT./SEC.
V_2 = 790 FT./SEC.
M = 17.22×10^{-4} SLUGS
h = 0.102 IN.
p = 1.57 IN.

STRAIN TRANSIENTS IN 24ST ALCLAD ALUMINUM PLATE AS A FUNCTION OF THE DISTANCE FROM POINT OF IMPACT.
r IS DISTANCE FROM POINT OF IMPACT.
h IS THE THICKNESS OF THE PLATE.

POINT	r/h	POINT	r/h	POINT	r/h
A	15	C	34	E	54
B	25	D	44	F	64

FIG. 16

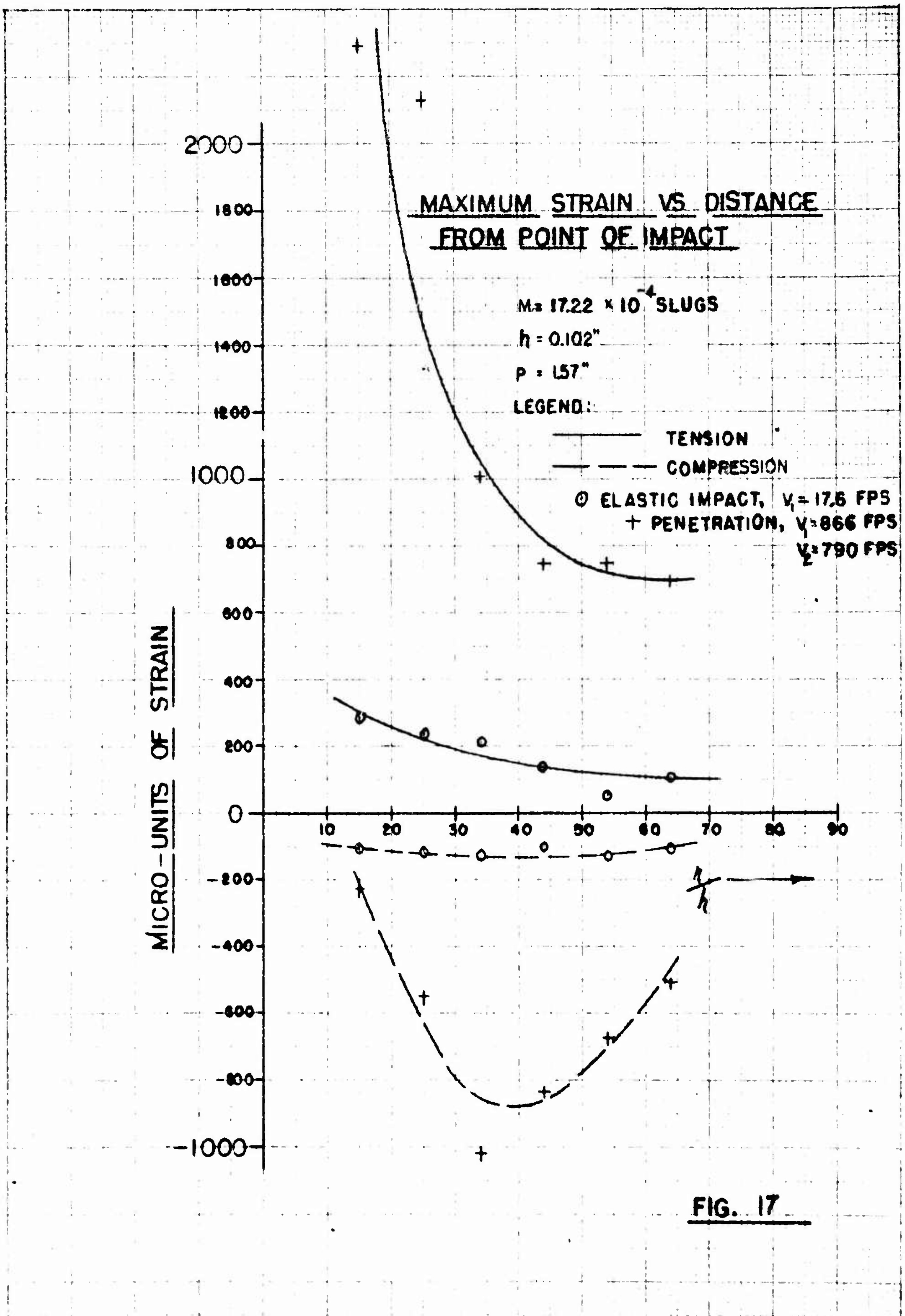
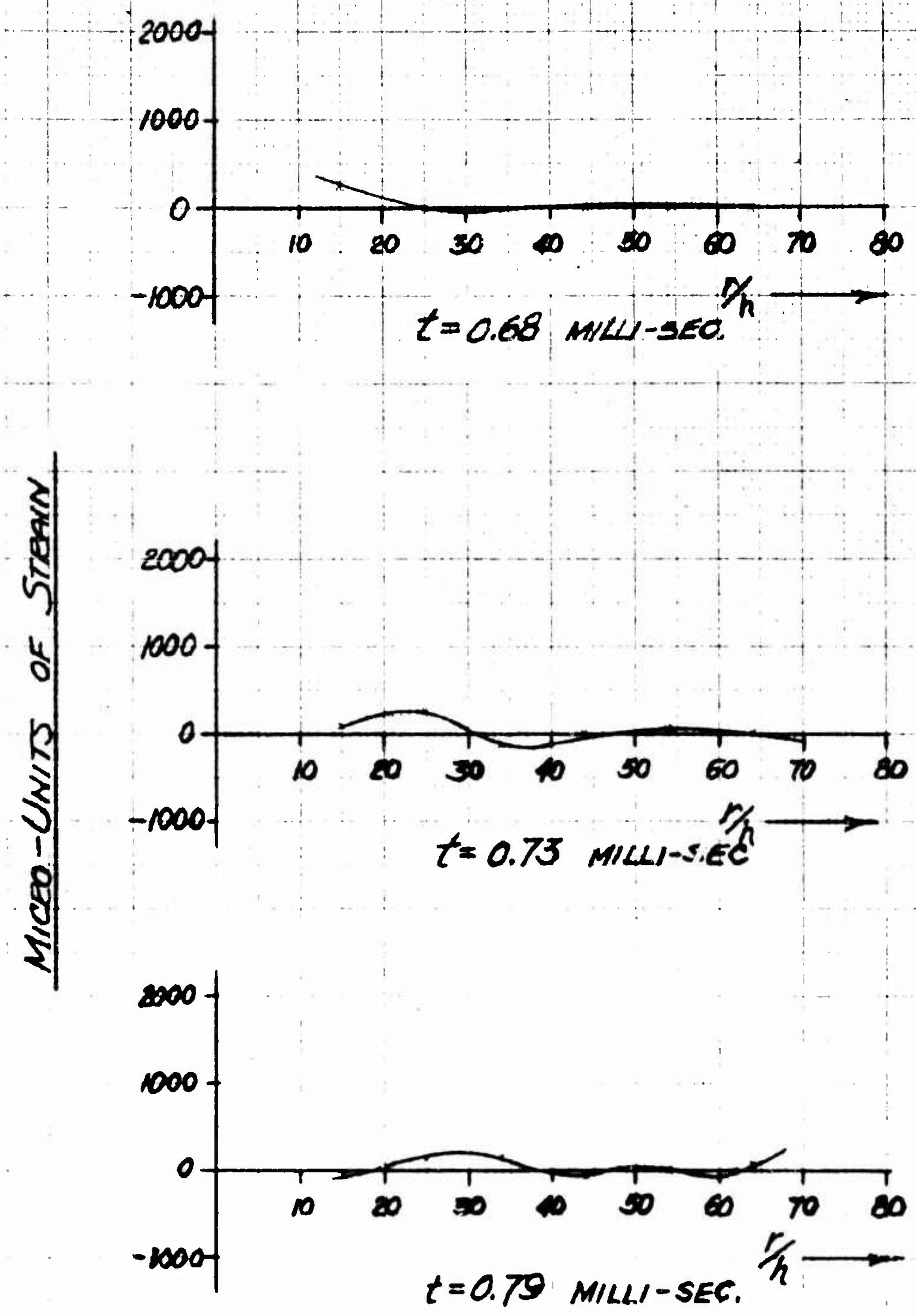
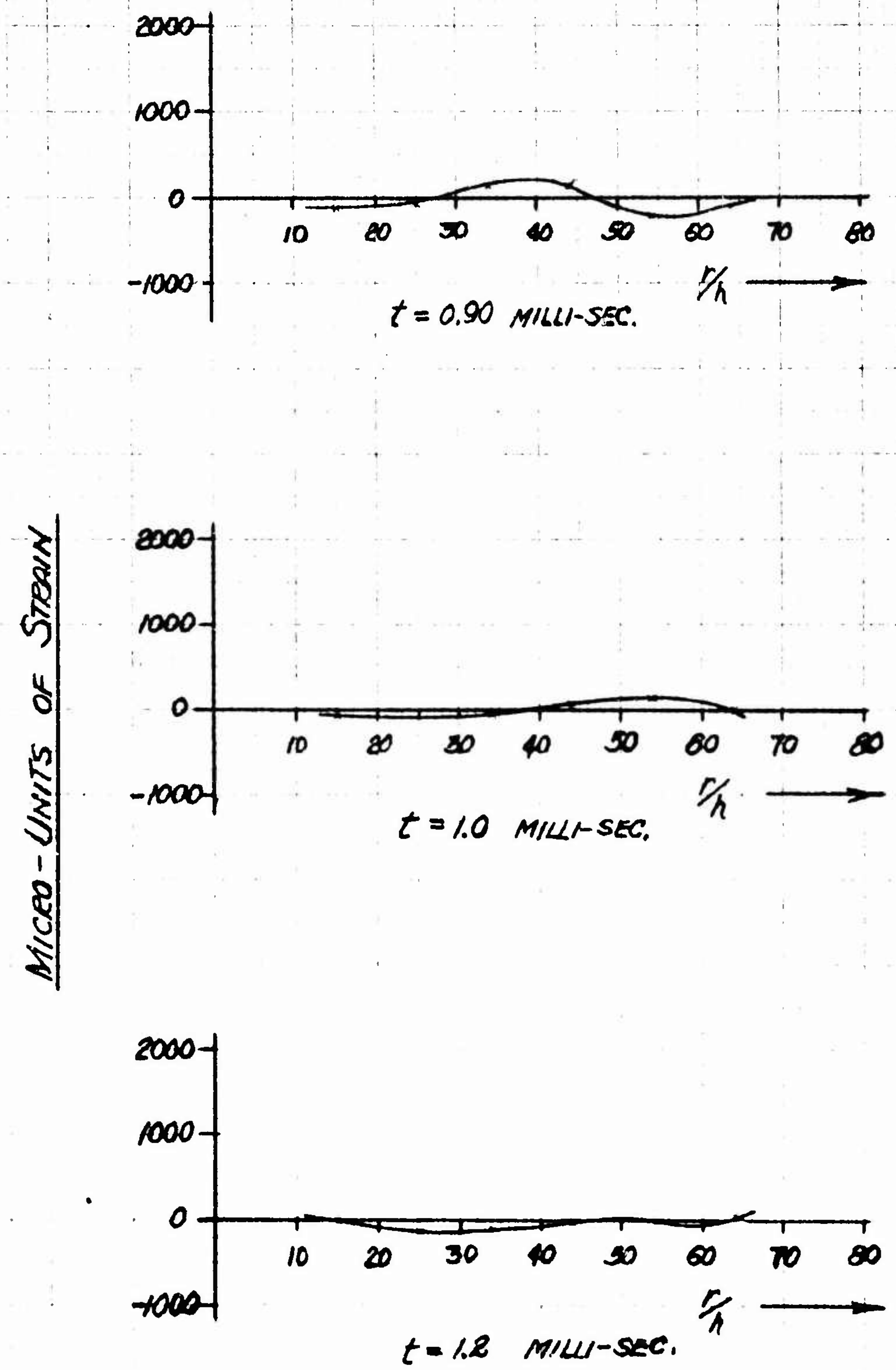

MAXIMUM STRAIN VS DISTANCE FROM POINT OF IMPACT
M = 17.22 × 10^-4 SLUGS
h = 0.102"
p = 1.57"
LEGEND:
TENSION
COMPRESSION
ELASTIC IMPACT, V1 = 17.6 FPS
PENETRATION, V1 = 866 FPS
V2 = 790 FPS
MICRO-UNITS OF STRAIN
2000
1800
1600
1400
1200
1000
800
600
400
200
0
-200
-400
-600
-800
-1000
10
20
30
40
50
60
70
80
90
r/h

FIG. 17



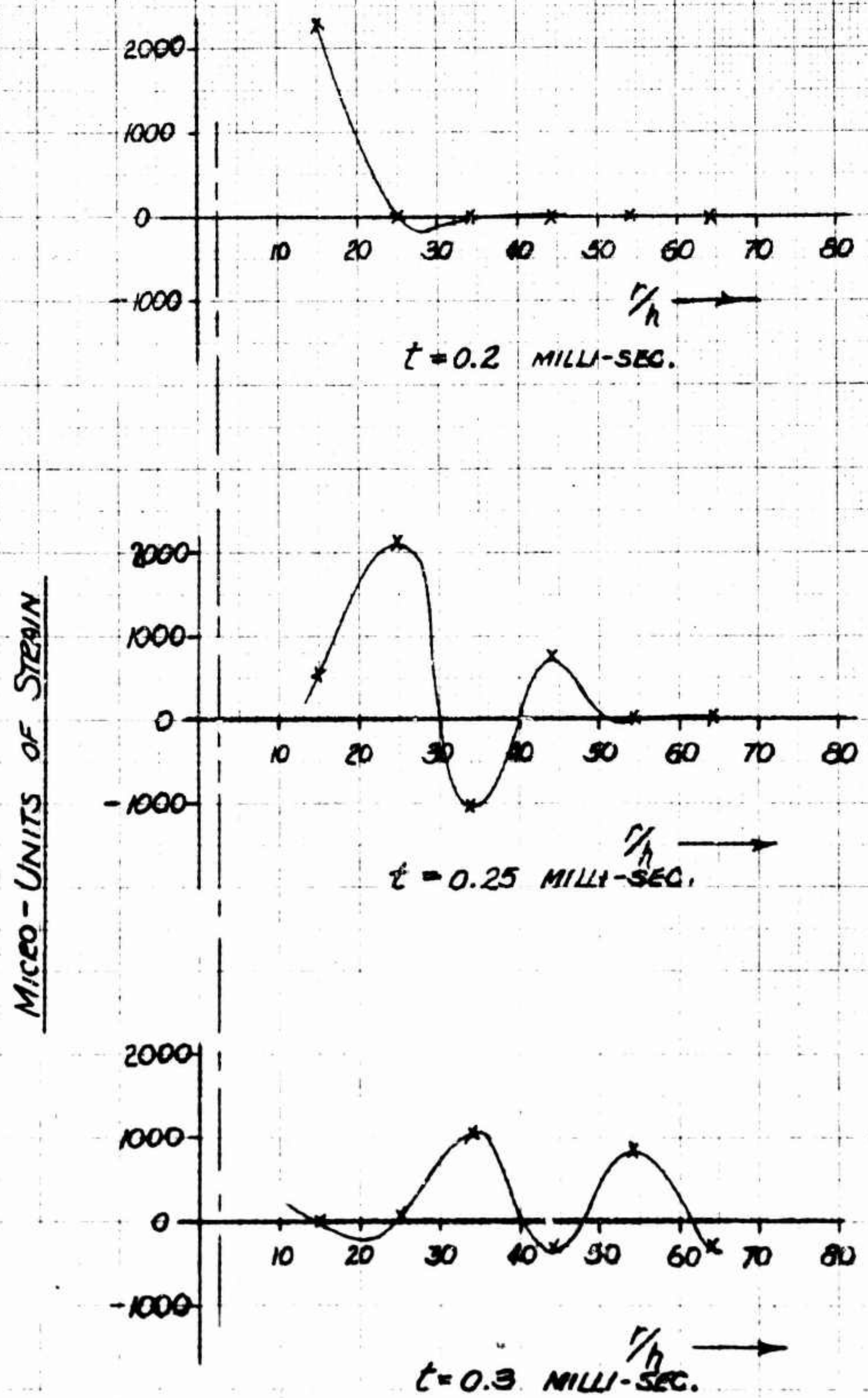
STRAIN VS. DISTANCE FROM POINT OF IMPACT RESULTING FROM ELASTIC IMPACT. TIME MEASURED FROM START OF OSCILLOGRAPH SWEEP.

FIG. 18A

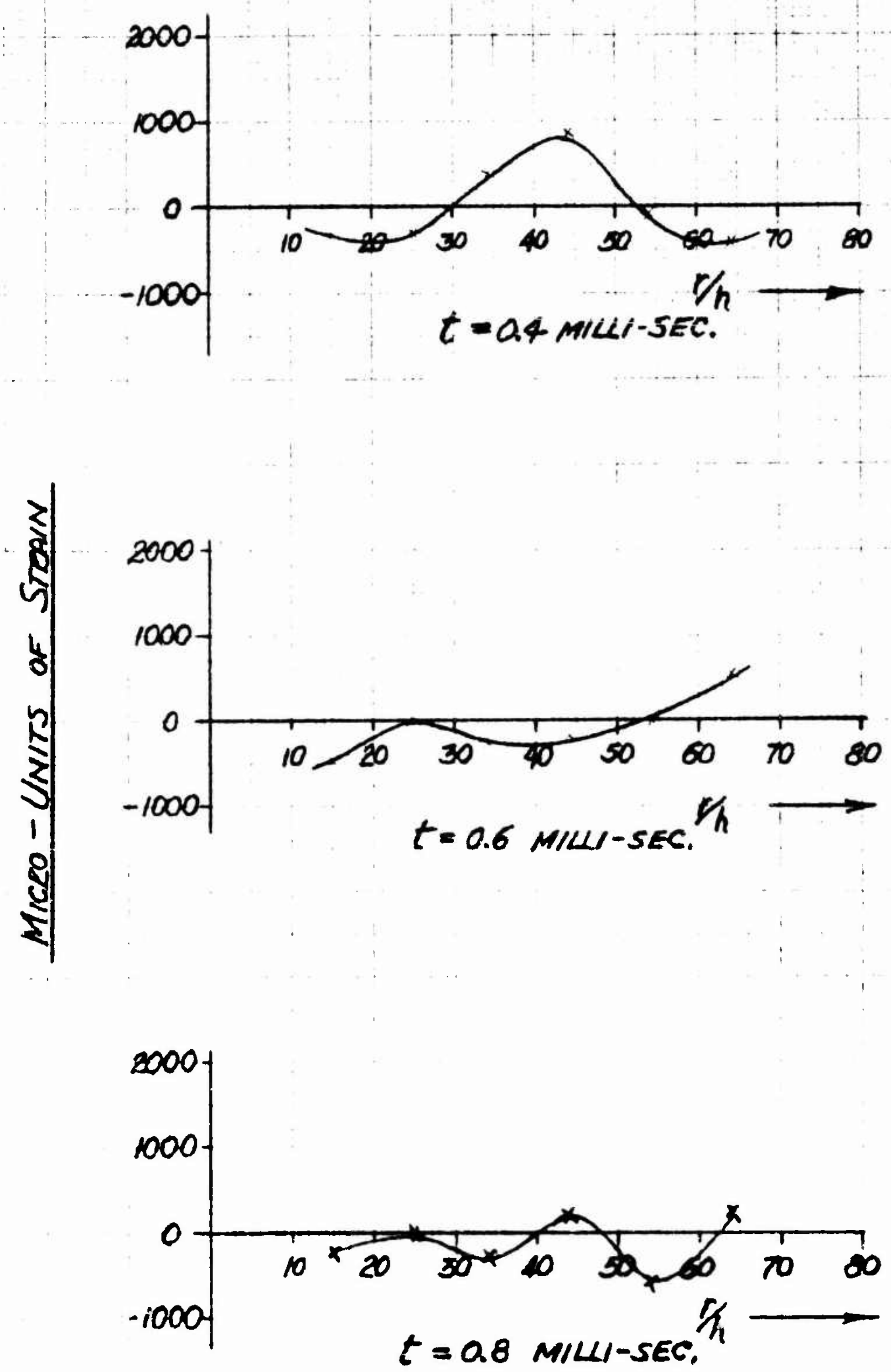


STRAIN VS. DISTANCE FROM POINT OF IMPACT RESULTING FROM ELASTIC IMPACT. TIME MEASURED FROM START OF OSCILLOGRAPH SWEEP.

FIG. 18B



STRAIN VS. DISTANCE FROM POINT OF IMPACT RESULTING FROM COMPLETE PENETRATION. TIME MEASURED FROM START OF OSCILLOGRAPH SWEEP. FIG. 19A



STRAIN VS. DISTANCE FROM POINT OF IMPACT. RESULTING FROM COMPLETE PENETRATION. TIME MEASURED FROM START OF OSCILLOGRAPH SWEEP.

FIG. 19B